TENTH ANNUAL REPORT

OF THE

UNITED STATES

GEOLOGICAL AND GEOGRAPHICAL SURVEY

OF THE

TERRITORIES,

EMBRACING

COLORADO AND PARTS OF ADJACENT TERRITORIES,

BEING A

REPORT OF PROGRESS OF THE EXPLORATION FOR THE YEAR 1876.

BY

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LETTER TO THE SECRETARY.

OFFICE U. S. GEOLOGICAL AND
GEOGRAPHICAL SURVEY OF THE TERRITORIES,
Washington, January, 1878.

SIR: I have the honor to transmit for publication the tenth annual report of the geological and geographical survey under my direction, embracing the completion of the work known as the survey of Colorado and portions of adjacent Territories. The systematic field investigation of the six rectangles which are included in what is called the Atlas of Colorado was commenced in the spring of 1873, and closed with the season of 1876. These six sheets embrace an area of rugged mountainous country of about 70,000 square miles. The field-work of the season of of 1876 was therefore entirely confined to the completion of the work in Colorado, and thus the area under investigation was located in the interior of the country, far remote from settlements, and among hostile bands of Ute Indians that attacked three of the parties the previous year.

The point of departure the past season was Cheyenne, Wyo. Two of the parties, with all their outfit, were transported by railroad to Rawlins Springs, and proceeded thence southward. The other two were sent by railroad from Cheyenne southward, one party to Trinidad and the other to Cañon City.

The primary triangulation party was placed in charge of A. D. Wilson, and took the field from Trinidad, the southern terminus of the Denver and Rio Grande Railroad, August 18, making the first station on Fisher's Peak. From this point the party marched by the valley of the Purgatoire, crossed the Sangre de Cristo range by way of Costilla Pass, followed the west base of the range northward as far as Fort Garland, making a station on Culebra Peak.

About six miles north of Fort Garland is located one of the highest and most rugged mountain-peaks in the West, called Blanca Peak, the principal summit of the Sierra Blanca group. On the morning of August 28, the party, with a pack-mule to transport the large theodolite, followed up a long spur which juts out to the south. They found no difficulty in riding to timber line, which is here about 12,000 feet above sea-level. At this point they were compelled to leave the animals, and, distributing the instruments among the different members of the party, proceeded on foot up the loose, rocky slope to the first outstanding point, from which a view could be obtained of the main peak of the range. Although this first point is only 600 feet lower than the main summit, yet the most arduous portion of the task was to come. The main summit is about two miles north of the first point, in a straight line, and connected with it by a very sharp-toothed, zigzag ridge, over which it is most difficult to travel, on account of the very loose rocks

and the constant fear of being precipitated down on either side several hundred feet into the amphitheatres below. After some two hours of this difficult climbing, they came to the base of the main point, which, though very steep, was soon ascended, and at 11 o'clock a. m. they found themselves on the very summit. From this point one of the most magnificent views in all Colorado was spread out before them. The greater portion of Colorado and New Mexico was embraced in this field of vision. This point is the highest in the Sierra Blanca group, and, so far as is known at the present time, is the highest in Colorado. The elevation of this point was determined by Mr. Wilson in the following manner: First, by a mean of eight barometric readings, taken synchronously with those at Fort Garland, which gave a difference between the two points of 6,466 feet; secondly, by fore and back angles of elevation and depression, which gave a difference of 6,468 feet. The elevation at the fort was determined by a series of barometric readings, which, when compared with the Signal Service barometer at Colorado Springs, gave it an elevation of 7,997 feet, making the Blanca Peak 14,464 feet above sea-level. This peak may be regarded, therefore, as the highest, or at least next to the highest, yet known in the United States. A comparison with some of the first-class peaks in Colorado will show the relative height:

	Feet.
Uncompahgre Peak, above sea-level	14, 235
Blanca Peak, above sea-level	14, 464
Mount Harvard, above sea-level	14, 384
Gray's Peak, above sea-level	14, 341
Mount Lincoln, above sea-level	14, 296
Mount Wilson, above sea-level	14, 280
Long's Peak, above sea-level	14, 271
Pike's Peak, above sea-level	14, 146

The foregoing table will afford some conception of the difficulty encountered in determining the highest peak where there are so many that are nearly of the same elevation. About fifty peaks are found within the limits of Colorado that exceed 14,000 feet above the sea-level.

From this point the party proceeded westward across the San Luis Valley and up the Rio Grande to its source, making two primary stations on the way, one near the summit district and the other on the Rio Grande pyramid. From the head of the Rio Grande the party crossed the continental divide, striking the Animas Park, and thence proceeded by trail to Parrott City.

After making a station on La Plata Peak, the party marched northwest across the broken mesa country west of the Dolores, making three stations on the route to complete a small piece of topography that had been omitted the previous year, on account of the hostility of the Ute Indians. After making a primary station on the highest point of the Abajo Mountains, the party turned eastward to Lone Cone, where another station was made. Thence, crossing the Gunnison and Grand Rivers,

they proceeded to the great volcanic plateau at the head of White River. The final station was made between the White and Yampah Rivers, in the northwestern corner of Colorado. During this brief season Mr. Wilson finished about one thousand square miles of topography, and made eleven primary geodetic stations, thus connecting together by a system of primary triangles the whole of Southern and Western Colorado.

In company with the triangulation party, Mr. Holmes made a hurried trip through Colorado, touching also portions of New Mexico and Utah. He was unable to pay much attention to detailed work, but had an excellent opportunity of taking a general view of the two great plain-belts that lie, the one along the east, the other along the west base of the Rocky Mountains. For nearly two thousand miles travel he had constantly in view the Cretaceous and Tertiary formations, among which are involved some of the most interesting geological questions. He observed, among other things, the great persistency of the various groups of rocks throughout the east, west, and north, and especially in the west; that from Northern New Mexico to Southwest Wyoming the various members of the Cretaceous lie in almost unbroken belts.

Between the east and the west there is only one great incongruity. Along the east base of the mountains the Upper Cretaceous rocks, including Nos. 4 and 5, are almost wanting, consisting at most of a few hundred feet of shales and laminated sandstones. Along the west base this group becomes a prominent and important topographical as well as geological feature. In the southwest, where it forms the "Mesa Verde" and the cap of the Dolores Plateau, it comprises upward of two thousand feet of coal-bearing strata, chiefly sandstone, while in the north it reaches a thickness of 3,500 feet, and forms the gigantic "hog-back" of the Grand River Valley.

While in the southwest he visited the Sierra Abajo, a small group of mountains, which lie in Eastern Utah, and found, as he had previously surmised, that the structure was identical with that of the four other isolated groups that lie in the same region. A mass of trachyte has been forced up through fissures in the sedimentary rocks, and now rests chiefly upon the sandstones and shales of the Lower Cretaceous. There is a considerable amount of arching of the sedimentary rocks, caused probably by the intrusion of wedge-like sheets of trachyte, while the broken edges of the beds are frequently, but abruptly, pressed up, as if by the upward or lateral pressure of the rising mass. He was able to make many additional observations on the geology of the San Juan region, and secured much valuable material for the coloring of the final map.

He states that the northern limit of ancient cliff-builders in Colorado and Eastern Utah is hardly above latitude 37° 45′.

The Grand River division was directed by Henry Gannett, topographer, with Dr. A. C. Peale as geologist. James Stevenson, executive officer of the survey, accompanied this division for the purpose of assist-

ing in the management of the Indians, who last year prevented the completion of the work in their locality by their hostility.

The work assigned this division consisted in part of a small area, containing about 1,000 square miles, lying south of the Sierra la Sal. The greater portion of the work of this division lay north of the Grand River, limited on the north by the parallel of 39° 30′, and included between the meridian of 108° and 109° 30′.

This division took the field at Cañon City, Colo., about the middle of August. The party traveled nearly west up the Arkansas River, over Marshall's Pass and down the Tomichi and Gunnison Rivers to the Uncompahgre (Ute) Indian agency. Here they secured the services of several Indians as escort in the somewhat dangerous country which they were first to survey. This area, lying south of Sierra la Sal, was worked without difficulty. It is a broken plateau country, and presents many extremely curious pieces of topography. Eleven days were occupied in this work.

The Grand River, from the mouth of the Gunnison River to that of the Dolores, *i. e.*, for nearly 100 miles, flows along the southern edge of a broad valley, much of the way being in a low cañon, 100 to 200 feet deep. The course of the river is first northwest for 25 miles; then, turning abruptly, it flows southwest, and then south, for about 75 miles. This valley has an average width of 12 miles. It is limited on the north and west by the "Roan or Book Cliffs," and their foot-hills, which follow the general course of the river. These cliffs rise from the valley in a succession of steps to a height of about 4,000 feet above it, or 8,000 to 8,500 feet above the sea.

From its crest this plateau (for the Book Cliffs are but the southern escarpment of a plateau) slopes to the north-northeast at an angle of not more than five degrees. It extends from the Wahsatch Mountains on the west to the foot-hills of the Park range on the east, and presents everywhere the same characteristics. The Green River crosses it, flowing in a direction exactly the reverse of the dip. It borders the Grand on the north for 100 miles, the crest forming the divide between the Grand and the White. On the south side of the crest are broken cliffs; on the north side, the branches of the White cañon immediately. This leaves the divide in many places very narrow, in some cases not more than 30 to 40 feet wide, with a vertical descent on the south toward the Grand River, and an extremely steep earth-slope (35° in many cases) at the heads of the streams flowing north to the White River. This crest, though not over 8,500 feet in height, is the highest land for a long distance in every direction.

After leaving the Uncompahgre agency, the party followed Gunnison's Salt Lake road to the Grand and down that river to the mouth of the Dolores, in latitude 38° 50′, longitude 109° 17′. At this point they turned northward, and went up to the crest of the Book plateau. They followed the crest to the eastward for upward of 100 miles, or to longi-

tude 108° 15′; then descended to the Grand and followed it up to longitude 107° 35′, and thence via the White River (Ute) Indian agency to Rawlins, where they arrived on October 23.

The whole area worked is about 3,500 square miles, in surveying which about sixty stations were made.

The geological work of this division, by Dr. Peale, connects directly with that done by him in 1874 and 1875. Sedimentary formations prevail in both districts visited during the past season.

The country first examined lies between the San Miguel and Dolores Rivers, extending northward and northwestward from Lone Cone Mountain. The general character of this region is that of a plateau cut by deep gorges or cañons, some of which, especially toward the north, extend from the sandstones of the Dakota group to the top of the Red Beds. The depth of the cañon, however, is no indication of its importance as a stream-bed, for, excepting the main streams, it is dry the greater portion of the year. There are not great disturbances of the strata, what folds do occur being broad and comparatively gentle.

The San Miguel River, on leaving the San Juan Mountains, flows toward the northwest, and, with its tributaries, cuts through the sandstones of the Dakota group, exposing the variegated beds lying beneath, that have generally been referred to the Jurassic. About 25 or 30 miles north of Lone Cone, the river turns abruptly to the west and flows west and southwest for about 15 miles, when it again turns and flows generally northwest, until it joins the Dolores. Between the San Miguel and Lone Cone the sandstones of the Dakota group, or No. 1 Cretaceous, are nearly horizontal, forming a plateau which, on approaching the mountains, has a cropping of Cretaceous shales.

Beyond the bend, the San Miguel flows in a monoclinal valley, in which the cañon walls are of the same description as in the upper part of its course. As the mouth is approached, the Red Beds appear. Between this portion of the course of the San Miguel and the almost parallel course of the Dolores, which is in a similar monoclinal rift, there are two anticlinal and two synclinal valleys parallel to each other. They are all occupied by branches of the Dolores. Lower Cretaceous, Jurassic, and Triassic strata outcrop, and present some interesting geological details, which will be fully considered in the report on the district. The Dolores River comes from a high plateau in a zigzag course, flowing sometimes with the strike, and sometimes with the dip of the strata. Its general course on the western line is about northwest, from which it turns to the northward and westward, finally changing to northwest again, to its junction with the Grand. It is in cañon the greater part of its course.

In the region of country north of Grand River, the geological formations extend uninterruptedly from the Red Beds exposed on Grand River to the white Tertiary cliffs forming the summit of the "Roan Mountains," or Book Cliffs. The Grand is generally in a cañon in the

Red Beds; on the north side the No. 1 Cretaceous sandstone forms a hogback, sloping toward the cliffs. Between the crest of this hogback and the cliffs there is a broad valley formed by the erosion of the soft Cretaceous shales which extend to the base of the cliffs, and in some places form their lower portion. The cliffs are composed mainly of Cretaceous beds, rising one above another in steps until an elevation of about 8,000 feet is reached. The summit is the edge of a plateau sloping to N. N. E. This plateau is cut by the drainage flowing into the White River from the south. These streams rarely cut through the Tertiary series.

Coal of poor quality is found in the sandstones of the Dakota group, and also in the sandstones above the Middle Cretaceous beds. Wherever noticed it was in their seams, and of little economic importance.

The White River division was directed by G. B. Chittenden, as topographer, accompanied by F. M. Endlich, as geologist.

The district assigned to this party as their field for exploration during the season of 1876, commenced on the eastward at longitude 107° 30′, joining on to the work previously done, and extended westward 30 miles into Utah Territory. Its southern boundary was N. latitude 39° 38′, while the White River formed the northern limit. In order to complete to the greatest possible advantage in the short time that could be allowed, it was determined to make the White River agency headquarters, and in two trips from there finish the work. About 3,800 square miles comprised the area surveyed.

In working up the topography of this district the party spent 48 days of absolute field-work, made 41 main topographical stations and 16 auxiliary ones, and traveled within the district about 1,000 miles. The party ascertained the courses of all the main trails, the location and quality of almost all the water, which is scanty throughout, and can map with considerable accuracy the topographical forms and all the water-courses. The area is almost entirely devoid of topographical "points," and the topographer is obliged to depend to a considerable degree on those far to the north and south for the triangulation. The country has heretofore been almost entirely unexplored, and was described by the nearest settlers as a broken cañon country, extremely dry. It was marked on the maps as a high, undulating plateau, with fresh-water lakes and timber. The party saw no lakes of more than 400 yards in diameter, and only two or three of these. The country is nearly all inhabitable, both winter and summer, and considerable portions of it valuable; and though three-quarters of it is within the Ute Indian reservation, the advantage of a more accurate knowledge of its character can readily be seen.

While working in the low, broken country of southwestern Colorado, last year, Mr. Chittenden made use of a light, portable plane-table, and found it of great value. It appeared at that time that its value was greatest in that class of country, and that in a low, rolling district, with

few prominent points, or in a high mountain country, it would probably be of little or no use. Altitudes were determined by the mercurial barometer, with a base at the White River Indian agency, and checked by a continuous system of vertical angles. The altitude of the agency has been determined by a series of barometric observations extending over two years and a half, and referred to railroad levels, and can probably be depended on to within a few feet. The altitude of the agency being about 6,500 feet, and the altitudes in the district ranging from 5,000 to 8,000 feet, makes its location the best possible in height for a barometric survey of the region.

It is the intention of the survey, during the coming year, to publish some tabulated results of the barometric work in Colorado, showing the system and its accuracy and reliability. This may be of use in future work, since the topography of the whole west must greatly depend on barometric determinations of altitude, and Colorado has furnished almost every possible phase of western topography.

The longest dimension of the work lying east and west, and the White and Grand Rivers running in approximately parallel courses, the district stretched from the White River up over the divide between the Grand and White, and embraced the heads of the lateral drainage of the former river.

The general topography is a gentle rise from the White River toward the south, and a sudden breaking off when the divide is reached into rugged and often impassable cliffs, known on the maps as the Roan or Book Mountains. The gentle plateau slope of the White River side is cut by almost numberless and often deep cañons, and in many cases the surface of the country has been eroded away, leaving broken and most picturesque forms, the lower benches generally covered with cedars and piñons, and the upper rich in grass.

There are four main streams draining into the White River within the limits of our work—a distance of something over 100 miles. The easternmost is a large running stream; the second, though tolerably good water may be found in pools in its bed, carries in the summer no running water for the greater part of its course; the third has for most of its length a trickling stream of the bitterest of alkali water, while the fourth and westernmost one is perfectly dry for some twenty-five miles from its mouth, and then forks, one branch containing pure, sweet water in pools, the other a running stream of bitter alkali. All of these streams have more or less good water at their heads. The party traveled nearly the whole length of all these water-courses, but found good trails only in the two middle ones. Trails, which traverse the whole district in every possible direction, keep mostly on the summits of the ridges and plateaus, and by taking care not to cross the cañons, the country is very easily traveled through.

The country is almost entirely destitute of timber, and has but little good water. It is, however, abundantly supplied with grass, and, espe-

cially in the winter season, must be well stocked with game. It seems well adapted to its present use as an Indian reservation, and is likely to remain for years to come more valuable for the Indians than it could be for settlement.

In the far western portion, and outside the limits of the reservation, one large vein of asphaltum and several small veins were found, and also running springs of the same material, all of which, if once reached by railroads, will prove of great commercial value. These deposits have been spoken of before, but their location has not been accurately determined. The principal vein seen by this party is at present about one hundred miles from railroad communication, but less than half that distance from white settlement, and is likely in the present rapid growth of that country to be within a few years made available.

According to the report of F. M. Endlich, the geology of this district is very simple, though interesting. Inasmuch as but one divide of importance occurred within the district, the work was somewhat simplified. This was formed by the Book Cliffs, between the drainages of the Grand on the south and the White on the north. Both these rivers flow, a little south of west, into Green River, which they join in Utah. From the junction of the Grand and Green downward the river is called the Great Colorado. Orographically, the region surveyed is comparatively simple. The Book Cliffs are the summit of a plateau about 8,000 feet above sea-level, continuing unbroken over to the Green River. Toward the south these cliffs fall off very steeply, forming deep cañons that contain tributaries of the Grand River. On the north side, with the dip of the strata, the slope is more gentle, although, in consequence of erosion, numerous precipitous cliffs are found. Descending in that direction, the character of the country changes. Instead of an unbroken slope, we find that the plateau has been cut parallel by the White River drainage, and the long, characteristic mesas of that region testify to the action of erosion. Approaching the river, constantly descending with the slight dip of the strata, the bluffs become lower and lower. Though the creek-valleys are wide, and at certain seasons no doubt well watered, the vegetation is that of an arid country. Dwarf pines, piñons, and sage-brush abound, to the almost entire exclusion of other trees or grass. Traveling down White River, this character is again found to change. A new series of bluffs, occasioned by heavy, superincumbent strata, gives rise to the formation of deep cañons. For forty-five miles the party followed the cañon of the White, that, no doubt, is analogous to that of the Green, and probably closely resembles that of the Colorado in its detail features. Vertical walls inclose the narrow river-bottoms, and the slopes of the higher portions are ornamented by thousands of curiously-eroded rocks. "Monuments" of all kinds, and figures that can readily be compared to those of animated beings, enliven the scenery, which otherwise would be very monotonous; 2,000–3,000 feet may be stated as the height of the walls inclosing the White River.

Geologically speaking, the district was one of singular uniformity. Traveling westward, the older formations reaching back as far as the Triassic, were found. This was followed by Cretaceous, which in turn was covered by Tertiary. About three-quarters of the region surveyed was found to contain beds belonging to this period. Owing to the lithological character of the strata, water was a rare luxury in this region, and men and animals were frequently dependent upon looking for springs. Farther west still the Green River group sets in, forming those numerous cañons of which that of the White River is one.

Having completed their work by October 14, the party marched eastward through Middle Park, and after twelve days of rain and snow reached Boulder City, Colo.

The field-work of the Yampah division during the past season was principally confined to a district of Northeastern Colorado, lying between the Yampah and White Rivers, and between Green River and the subordinate range of mountains that lies west of and parallel with the Park range. The area is embraced between parallels 39° 30′ and 40° 30′, and meridian 107° 30′ and 109° 30′.

The party consisted of Mr. G. R. Bechler, topographer, directing, accompanied by Dr. C. A. White, the well-known geologist. They proceeded southward from Rawlins Springs, a station on the Union Pacific Railroad, August 6, toward their field of labor. From Rawlins Springs to Snake River, a distance of eighty miles, table-lands form the chief feature of the topography, while from Snake River to the Yampah River the surface is more undulating and thickly covered with sage. Between the Yampah and White Rivers, a distance of fifty miles, the country is mountainous, and on the divide between the Yampah and White Rivers the elevation is 8,000–9,000 feet. Mr. Bechler, after having formed the geodetic connection with the work of previous years, concluded to finish the more mountainous portion of the area assigned to him, which began from a line of meridian with the White River agency, and extended westward to about 108° 10′. Here the party found water and grass in abundance, with one exception. The plateau country, however, was so destitute of water and so cut up with dry gorges or cañons, with scarcely any grass or timber of any kind, that traveling was rendered very difficult. The party therefore made White River its base of supply for water and grass, making side trips into the barren hill-tops or plateaus in every direction.

From the Ute agency, which is located approximately in latitude 38° 58′ and longitude 107° 48′, the White River takes an almost due west course for 15 or 18 miles, most of the way through an open valley, with here and there narrow gorges. About 50 miles from the agency the river opens into a broad, barren valley, with only here and there scanty patches of vegetation. Soon after the river enters a deep cañon, with vertical walls 2,000 feet or more in height, and continues to increase in depth until the river flows into the Colorado of the West.

The Yampah or Bear River deviates from a westerly course only for a few miles occasionally. Like White River, it flows through a plateau country, which rises gently from the river back for a distance of about eight miles. South of the river lie the Williams River Mountains, which have a gradual slope to the north. Williams Fork, flowing from a southeastern direction, joins the Yampah River west of the junction. The Yampah traverses the country more or less in a cañon, occasionally emerging into an open, grassy valley, then enters a deep cañon, cuts through the Yampah Mountains, when it joins with the Snake River. The place of junction resembles a fine park, surrounded on all sides with eroded terraces and plateau spurs that rise by steps to the divide on either side. This park is about eight miles in length from east to west. After leaving this park the river enters a huge fissure in the mountains, where it remains until, completing its zigzag course, it joins the Green River in longitude 109° 40′ and latitude 32°. After the junction with the Yampah, the Green River continues in a cañon for fourteen miles, where it passes through the picturesque palisades of Split Mountain into an open, broad valley, longitude 109° 15′, latitude 40° 28′, from which point it takes a southwest direction through the Wamsitta Valley, where it unites with the White River. Into both White and Yampah Rivers numerous branches extend from either side, forming deep cañons the greater portion of their length. We may say, in brief, that the sides of the valleys expand and contract, at one time forming the beautiful grassy valleys which in olden times were celebrated as the favorite wintering places for the trappers, or contracting so as to form narrow cañons or gorges with walls of varied height.

The walls of Yampah Cañon average 1,000 feet, while the mountains, receding back to the northward, attain an elevation of 4,200 feet, while the highest point of the plateau on the south side is 3,400 feet above the river-level.

Of the plateaus between White and Yampah Rivers, Yampah plateau is the largest, and occupies an area of 400 square miles. The surface of the summit is undulating, and on the south side it presents a steep face, several hundred feet in height, covered with débris, rendering it almost inaccessible. This plateau is covered with excellent grass, and gives origin to numerous springs, all of which dry up within a short distance of their source.

As a whole, this district is very arid, barren, and almost destitute of tree vegetation.

The total number of stations made by Mr. Bechler in the district assigned to him was 40, and the entire area was about 3,000 square miles. Barometric observations were made whenever needed, and about 2,000 angles of elevation and depression, with fore and back sights, so that material for obtaining correct altitudes is abundant.

The rocks of this district embrace all the sedimentary formations yet recognized by the investigators who have studied the region that lies

between the Park range and the Great Salt Lake, namely, from the Uinta quartzite (which underlies the Carboniferous) to the Brown's Park group, or latest Tertiary, inclusive. Not only has the geographical distribution of these formations been mapped, but all the displacements of the strata have been traced and delineated. The last-named investigations bring out some interesting and important facts in relation to the orographic geology of the region, especially as regards the eastern termination of the great Uinta uplift and the blending of its vanishing primary and accessory displacements with those of the north and south range above mentioned. Much information was also obtained concerning the distribution of the local drift of that region, the extent and geological date of outflow of trap, &c.

The brackish-water beds at the base of the Tertiary series, containing the characteristic fossils, were discovered in the valley of the Yampah. They are thus shown to be exactly equivalent with those, now so well known, in the valley of Bitter Creek, Wyoming Territory. These last-named localities were also visited at the close of the season's work, and from the strata of this horizon at Black Buttes station three new species of *Unio* were obtained, making six clearly distinct species in all that have been obtained, associated together in one stratum at that locality. They are all of either distinctively American types or closely related to species now living in American fresh waters. They represent by their affinities the following living species: *Unio clavus*, Lamarck; *U. securis*, Lea; *U. gibbosus*, Barnes; *U. metaneorus*, Rafinesque; and *U. complanatus*, Solander. They are associated in the same stratum with species of the genera *Corbulo*, *Corbicula*, *Neritina*, *Viriparus*, &c., and which stratum alternates with layers containing *Ostrea* and *Anomia*.

The close affinity of these fossil *Unios* with species now living in the Mississippi River and its tributaries seems plainly suggestive of the fact that they represent the ancestry of the living ones. An interesting series of facts has also been collected, showing that some of the so-called American types of *Unio* were introduced in what is now the great Rocky Mountain region as early as the Jurassic period, and that their differentiation had become great and clearly defined as early as late Cretaceous and early Tertiary times. Other observations suggest the probable lines of geographical distribution during the late geological periods of their evolutional descent, by one or more of which they have probably reached the Mississippi River system and culminated in the numerous and diverse forms that now exist there.

The work of the season of 1876 shows very clearly the harmonious relations of the various groups of strata over vast areas, that although there may be a thickening or a thinning out of beds at different points, they can all be correlated from the Missouri River to the Sierra Nevada basin. The fact, also, that there is no physical or paleontological break in these groups over large areas from the Cretaceous to the Middle Tertiary is fully established. The transition from marine to brackish water forms

of life commences at the close of the Cretaceous epoch, and, without any line of separation that can yet be detected, continues on upward until only purely fresh-water forms are to be found. Dr. White, an eminent paleontologist and geologist, says that the line must be drawn somewhere between the Cretaceous and Tertiary epochs, but that it will be strictly arbitrary, as there is no well-marked physical break to the summit of the Bridger group.

If, however, a well defined nonconformity is found to exist it will be examined with great care and its proper value given, but up to the present time the views as stated above are sustained by the facts, so far as the investigations by this survey have extended.

Excellent progress has been made in the report on the general geology of the country west of the 94th meridian. It is the intention of the survey to discuss the geology of the portions of the West which have been reported upon either by the parties under my charge or by others. It is believed that there is a remarkable unity in the geological structure of the entire area; that although formations of the same age have received a great variety of local names, they will be so correlated that a single system of classification will include them all. As an illustration the pliocene lake basins which have received a variety of names, as Loup Fork, North Park, Uintad Group, Brown's Park, Humboldt Group, may all be brought under one generic term and into one geological horizon. The Cretaceous divisions which are so well marked in the Northwest, and have already received suitable geographical names, can be extended to the Pacific Coast, and all the fragments be brought into one group or another. I had intended to publish several chapters on this subject in this report, but the pressure of other duties prevented their completion in time.

In order to show the unity more perfectly a map of the country west of the 94th meridian has been prepared, dividing the area into twenty-two rectangles, each of which on a scale of twelve miles to one inch will form a map of the size of the "General Geological Map" in the "Atlas of Colorado." It is believed that in no other way can a systematic idea of the geology as well as the geography be obtained.

The relation of the topographical surveys to the general system of public land surveys is important, and the economic resources have always been a leading feature in our plans. The following paragraphs from the letter of instructions of the Secretary of the Interior show the importance attached by the department to these features:

In the prosecution of your surveys you will, when necessary, consult such public land surveys as have been made under this department, in the field of your work, for the purpose of connecting the established lines with your system of triangulation, and of accurately designating on your maps the position of mineral claims. You will determine as far as possible the boundaries of Territories and Indian reservations, and mark the same by suitable monuments. You will also ascertain the position of all agricultural lands, and of such mineral lands as you may discover, by trigonometrical measurements, placing suitable monuments thereon for the guidance of the surveyors-general of the several districts which may be explored by you.

It will be borne in mind that the ultimate design to be accomplished by these surveys is the preparation of suitable maps of the country surveyed for the use of the government and of the nation, which will afford full information concerning the agricultural and mineral resources, and other important characteristics of the unexplored regions of our Territorial domain. To this end, a general plan for mapping the area of your survey should be followed. Such a plan was adopted by this department last year, and accompanied your instructions for that year. You will continue to conform to said plan, and will make such scientific observations, touching the geology, geography, mineralogy, and meteorology of the country surveyed by you, as may be necessary for the preparation of such maps. In addition thereto, you will obtain the necessary information for the preparation of charts, upon which shall be indicated the areas of grass, timber, and mineral lands, and such other portions of the country surveyed as may be susceptible of cultivation by means of irrigation; and will ascertain and report upon the best methods for accomplishing this result.

The economic map in the "Atlas of Colorado" presents an example of the minuteness of detail with which the economic features of a country may be laid down on a chart. This map, covering an area of over 100,000 square miles, shows with remarkable clearness, by means of colors, the agricultural and pastoral lands, the pine and other forests, the barren lands, and those above timber-line—all the valuable mineral deposits, as coal, silver, and gold. An excellent article on the economic resources of Colorado, by Mr. Gannett, is embodied in this report. In all the annual reports of the survey since 1867 more or less attention has been given to this subject.

Before proceeding to a description of the triangulation in Colorado and its relations to the land surveys, it may be well to give a general description of the method of locating points by triangulation.

In this method the only direct measurements made are those of one or more base lines; all other measurements are derived from those by the measurements of angles.

For the measurement of a base line, a flat extent of country, of a suitable length, is selected. The ground should be as nearly horizontal as possible, and the two ends, and, if possible, all points of the proposed base, should be intervisible. The length of the line should be measured with all the accuracy possible under the circumstances, as any error in this measurement is increased manifold in the subsequent triangulation.

In the Coast Survey the lines are measured by metal bars, compensated for temperature, and the contact between the ends of the bars is made by a microscope. In this case the operation of measuring and remeasuring a base five miles long occupies several weeks, and the error does not exceed a small fraction of an inch.

In the work of this survey, which does not admit of the devotion of so much time and expense, these measurements have been made with a 100-foot steel tape. The measurements are, of course, corrected for temperature, slope, and error of tape, and are reduced to sea-level. The base measured, a distance of perhaps 5 or 6 miles, the next step is to "expand" it, that is, to obtain from this known distance of 5 or 6 miles

the accurate length of a line 20, 30, or 40 miles in length, the mean distance between stations of the triangulation.

For this purpose, points are selected on the right and left of the base line, at such distances from it that the triangles formed by each of these points, and the two ends of the base, will be "well conditioned"; that is, that the angles of the triangles will be as nearly equal as possible. Then all of the angles of each of these triangles are measured.

Now, were these angles measured perfectly, the sum of the three of any triangle would be 180° plus the spherical excess. The amount of the discrepancy is an indication of the accuracy of the work. Now, in each of these triangles there is given a side and the three angles, and a simple trigonometrical calculation gives the lengths of the other sides; these other sides, thus calculated, furnish bases for further triangles, each larger than those used before, and thus the enlargement goes on until the normal length of sides of triangles is reached. This completes the expansion, and thence the triangulation goes on by the simple measurement of angles, the sides of the triangles being kept as nearly as possible of the same length and the angles as nearly equal as possible.

A second base is usually measured as a check on the first. From it an expansion is made, and the work connected with that from the first.

To ascertain the *direction* or azimuth of these lines, it is necessary to know only the direction of any one of them, although practically the directions of several are measured, as checks on one another. The measurement consists in measuring the angle between the line and some slow-moving star, usually the pole star, whose distance from the north pole is known at the time. Now, this system of triangulation is consistent in itself, but its position on the earth's surface is unknown. To determine this requires the aid of astronomy. One or more of the stations in this triangulation must be fixed by astronomical means, and the character of the work is such as to warrant the employment of the best instruments and the most refined methods for the determination of the latitude and longitude of this or these points. For the determination of the latitude, we use the zenith telescope, and the method of zenith distances of stars. To describe this method would require more space and technical language than could be used here. Suffice it to say, that this method determines the latitude within a few tenths of a second, where a second is about 100 feet.

The longitude is determined by the comparison of the local time of the station with that of some point whose position is known. This comparison is made by telegraph. The *beats* of the chronometer are transmitted back and forth by telegraph, and recorded side by side on paper, by an ingenious instrument known as the chronograph.

The difference between the local times of the two stations is the difference in longitude. This local time is determined at each station by observing the transits of stars, whose positions are known, with a transit instrument. These observations give the error of the chronometer and

hence the local time. By this method the longitude of a point can be determined within 30, 40, or 50 feet at the worst.

Now, the latitude and longitude of a point being known, those of all other points also are determined, as their distances and directions from the first point are given by the triangulation, and the whole system is correctly placed on the earth's surface.

In the inception of the work in Colorado a base line was measured near Denver, mainly on the track of the Kansas Pacific Railroad. Two measurements were made of it, with a steel tape 100 feet long, under a tension of 16 pounds. The end of each 100 feet was marked by a knife-edge on the railroad track, or on a low stool. The profile of the line was leveled, and the temperature of the tape was constantly measured.

The results of two measurements, corrected for temperature and slope, are respectively 31,861.304 and 31,863.102 feet, showing a discrepancy of about 1.8 feet, or about $\frac{1}{15000}$ of the length. It was, of course, corrected for error of tape, and reduced to sea-level.

From this base, triangulation was extended and carried into the mountains. Then a second base was measured in San Luis Valley. The methods were the same, and the results better than in the case of the Denver base. Six days were occupied in its measurement and re-measurement. The corrected results are as follows: 28,522.74 and 28,522.558 feet, a difference of only $\frac{18}{100}$ of a foot in $5\frac{1}{3}$ miles.

Connecting the triangulation from those two bases with one another, the error was found to be only $9\frac{1}{2}$ inches to the mile. This error is the sum of the errors of the measurements of the bases and of the triangulation as brought through nearly 200 miles. The angles were measured with theodolites whose circles were 8 inches in diameter, receding to $10''$ of arc. All the stations were marked by monuments 5 to 10 feet in height.

In the whole scheme of triangulation of Colorado, 143 complete triangles have been measured, with a mean error of closure of $13''.3$. The errors of measurement of the sides of the triangles will not exceed $\frac{1}{2}$ of a foot per mile, and the error of location of the primary stations is not greater than 25 feet. The area covered in Colorado is about 70,000 square miles.

For the location of the work in latitude and longitude, it was deemed best, on account of the expense of instruments, &c., to ask the Coast Survey, which is completely fitted in this respect for the work, to determine the latitude and longitude of several points for us. This they very kindly consented to do, and established the position of points in Denver, Colorado Springs, and Trinidad, Colo., for us with the greatest accuracy.

The next point is, how these locations are to be used for the inception of land surveys in isolated mountain valleys, and for the elimination of errors in the work of these surveys.

We may premise that either case requires more knowledge of surveying

than usually falls to the lot of a deputy surveyor, and that they will not utilize these points unless required so to do by law.

In the first of the above cases, we may suppose a valley, surrounded by high, rugged mountains, over which it would be very expensive to run a line at all, and impossible to do it with any approach to accuracy. Suppose that a mountain peak on the edge of this valley has been accurately located and its latitude and longitude given. The latitude and longitude of the point in this valley which should be the nearest township corner to this peak can easily be deduced by calculation, whence the distance and direction of this supposed township corner from the peak can also be computed. All that remains to be done, then, is to find the point in the valley at the requisite distance and direction from the peak, and this point is the township corner, whence the survey may be carried on in the usual manner. Take, as an example, the valley of the Uncompahgre, in Western Colorado, a large, fertile valley, which will soon require to be surveyed. The nearest surveys are now, I understand, on the Gunnison, at the mouth of Cochetopa Creek. To carry a base line thence to the Uncompahgre Valley will require the chaining of about 50 miles over rugged mountain country. Instead of this, take Mount Sneffles, a peak in the San Juan Mountains overlooking this valley, as a starting point. The township corner which will come nearest to this peak is, we will say, the 8th township, *i. e.*, 48 miles west of the last one at the mouth of Cochetopa Creek, where the surveys now extend. Knowing the latitude and longitude of the latter point, that of the supposed corner in the Uncompahgre Valley, being 48 miles farther west, can easily be computed, and knowing this, its distance and direction from Mount Sneffles can also easily be computed, and the line run from the summit of Sneffles to the required point.

In the second case, that of using these points as checks on the accuracy of the land surveys, I would recommend that the surveyors, whenever, in running lines, they pass near a located point, be obliged to connect their lines with it by chaining. Then the astronomical position of the corner, as determined by their work, and by connection with the station of triangulation, should agree. If they do not, the most of the error is in the land surveys, and they should be corrected accordingly. This will not only vastly increase the accuracy of the work, but will prevent the manufacture of the notes in camp.

Moreover, these geodetic stations, which are in all cases mountain peaks whereon the station is marked by an indestructible stone cairn, would furnish points of reference for all time, in case disputes should arise concerning boundaries, &c.

Monuments are built on all the stations in the primary triangulation, and on those of the secondary triangulation, wherever material for their construction is available. They are built of stone, simply piled up in the form of a pyramid; are of a minimum height of 5 feet, thence up to 15 feet.

Where material is immediately at hand, as is usually the case, a monument five to six feet high can be erected in half an hour by two men.

Our experience has been that the erection of these monuments requires no additional force, and but a trifling amount of time, and hence need involve no extra expense whatever.

On our final maps, those stations on which monuments have been erected will be appropriately marked, and their correct positions, in latitude and longitude, will be given.

The public-land surveys, by use of these monuments, will be enabled to effect a great saving in running base-lines and guide-meridians over difficult mountain country. Also, the large errors, which such lines are almost sure to involve, are avoided.

A more detailed account of the publications of the survey and the office work will be given in the annual report for 1877, which will go to press in October.

With the hope that this report will prove of value to the government and to science it is respectfully submitted.

I have the honor to be your obedient servant,

F. V. HAYDEN,
United States Geologist.

To Hon. CARL SCHURZ,
Secretary of the Interior.

PART I.

GEOLOGY.

REPORT OF C. A. WHITE, M. D.

LETTER OF TRANSMITTAL.

WASHINGTON, D. C., *November* 1, 1877.

SIR: I have the honor to transmit herewith my report on the geology of a portion of Northwestern Colorado, it being the district that was assigned to me for examination during the season of 1876.

The amount of time I was enabled to give to the work during that season was comparatively short, and my movements in the field having been dependent on those of the topographical party, the results were necessarily incomplete; but having been able to devote a part of the season of 1877 to the same district, I have succeeded in working out its structural geology with a good degree of satisfaction.

My method of prosecuting the work was, besides the ordinary examination of the rocks and the surface of the region as I traversed it, to go upon the higher and more prominent points and make my field-notes and sketches there. Besides visiting all the topographic stations in this way, I established many note stations of my own, also. Thus the whole district was examined in detail, and every feature of its geological structure was seen and traced by my own eyes; which the slight accumulation of soil or *débris* upon the surface and the sparseness of vegetation in that arid region rendered entirely practicable.

On a subsequent page I have correlated the general section of the rocks of my own district with those prepared by Powell and King, respectively, for adjoining districts, as I understand them after a considerable personal examination of the geology of those districts.

This report is chiefly confined to the structural geology of the district, which is found to possess peculiar interest; but many interesting facts were also observed concerning its economic and surface geology, drift, trap-outflows, &c., which are recorded on following pages.

Very respectfully, yours,

C. A. WHITE.

DR. F. V. HAYDEN,
In charge of the Geological and Geographical Survey of the Territories.

REPORT ON THE GEOLOGY OF A PORTION OF NORTHWESTERN COLORADO.

CHAPTER I.

INTRODUCTION.

The district upon which the following report is made, is included within the following boundaries: The eastern boundary is approximately upon a straight line drawn from a point where the meridian of longitude 107° 50′ west from Greenwich crosses White River, to where the meridian of 107° 25′ crosses Yampa River. The northern boundary is the parallel of north latitude 40° 30′; the southern is the channel of White River, and the western the meridian of 109° 30′. The area thus inclosed contains about 2,400 square miles. The Yampa River has its course near, and its general direction approximately coincident with the northern boundary just mentioned; bending and meandering on each side of it, so that, in general terms, the Yampa and White Rivers may be said to be respectively the northern and southern boundaries of the district. The meridian which constitutes the western boundary is thirty minutes west of the joint boundary-line between Colorado and Utah. The eastern boundary is not a distinctly defined one, because this district adjoins the one which was surveyed by the late Mr. A. R. Marvine, and which was bounded on the west by no definite geographical features. It is, however, practically as above stated.

The Yampa and White Rivers are both tributaries of Green River, which is itself the principal tributary of the great Colorado River of the West. This district is thus shown to be upon the Pacific-drainage slope of the continent, the great Rocky Mountain chain lying wholly to the east of it, but some of the western foot-hills of which rest upon its eastern border.

Strictly speaking, this district is only in part a mountainous one, although it is by no means a plain-country in any considerable part. It lies between two separate and important mountain systems, namely those of the Uinta and the Park Ranges (the latter being a subordinate portion of the great Rocky Mountain Range), each of which, especially the former, occupies a portion of its area. The Uinta Mountains have an east and west, and the Park Mountains a north and south trend, or, in other words, their axes are approximately at right angles with each other. The eastern end of the Uinta Range occupies a large portion of the northwestern part of the district, while the eastern portion of the district extends up to the western foot-hills of the Park Range.

The district is an elevated one, aside from its mountains. The lowest level within its limits, which is the surface of Green River, is about 5,000 feet above the level of the sea, while the higher points of land, both those of the eastern and northwestern portions of the district, reach an altitude of more than 9,000 feet above the level of the sea. In consequence of this great elevation and of the dryness of the climate, vege-

tation is scant and in large part dwarfed. This scantiness of vegetation, and the rapid removal of the *débris* of disintegrated rock in time of rains and melting snows, and consequent flooding of the drainage-channels, leaves the surface, especially that of the hill and valley sides, so bare that the strata, for the rocks are all stratified, are as distinctly seen as the leaves of a book.

The geologist, therefore, may go to the top of any of the mountains or higher hills and see the geological structure of the neighborhood spread out below him like a well-drawn picture; and even the geological structure of the more distant parts of the landscape may often be accurately determined from these elevated points of observation. These conditions of the surface give great advantage to the geologist; not only insuring great accuracy in his work, but they also enable him to accomplish it with extraordinary rapidity. This explanation, besides setting forth an interesting fact, is also really due to those who, not personally acquainted with the peculiarities of that region, may compare the detailed reports that geologists have made upon various portions of it with the comparatively short time they are known to have been engaged upon the field-work.

In no humid country, where the *débris* of disintegrated rock profusely and often deeply covers the underlying strata, can the details of geological structure be so accurately ascertained, even by years of careful search, as it may be done in a region like this, within a few days.

CHAPTER II.

SURFACE FEATURES.

MOUNTAINS.

Although the elevation, above the level of the sea, of the hills of the eastern portion of the district is quite as great as that of any other portion, the more prominently distinct mountain masses within its limits are located in the northwestern quarter, and consist of closely adjacent and inseparable portions of the Uinta system. The Yampa Plateau constitutes the principal one of these mountain masses, the others being appendages or prolongations from it, as itself is an appendage or accessory fold of the great Uinta Uplift, lying upon the southern side of the eastern end of that chain. Section Ridge and Split Mountain are western prolongations or spurs from Yampa Plateau, and Midland Ridge is a long accessory fold and eastern prolongation from the same, at least as a topographical featuce. The latter is not so high as the plateau except at its western end, but yet it forms a very conspicuous topographical feature of the region; its bright red strata making it also a very conspicuous geological one. Beyond this group of subordinate mountain masses, to the northward and northwestward, lies the main fold of the Uinta system; and stretching to the westward its great chain of peaks is seen, with their patches of perennial snow glittering in the midsummer sunlight.

Junction and Yampa Mountains are remarkable, isolated mountains, each about 2,000 feet high above the surface of the lowland of the basin out of which they rise; but they both belong to the Uinta system and lie upon the vanishing extension of the flexure of the great Uinta Uplift; which extension I have called the axial flexure. The first-named mountain lies some three or four miles east of the eastern end of the Uinta chain, and the latter, which must not be confounded with Yampa Plateau, lies some 15 or 16 miles still further eastward, in line with the great Uinta Axis. The structure and relations of all these mountains will be discussed in a subsequent chapter.

Although the elevation of the eastern portion of the district is quite as great as that of the mountain masses of the northwestern portion, the rise to the eastward is so gradual, and the surface comparatively so little broken into separate mountains within the eastern borders of the district, that it is not, strictly speaking, mountainous there. Just beyond its limits to the eastward there is a broad elevated district called the White River Plateau. This plateau has been largely formed as such by a great trap-outflow, the borders of which are now cut by erosion into deep gorges and ravines, among which White River and Williams Fork of the Yampa have their rise.

There are some other mountain masses in the more central portions of the district, left as such by the deepening of the drainage-valleys by erosion, that, although they are really important features, have been designated by distinctive names only so far as it was found necessary

to apply them as aids in descriptive geology. These are the Danforth* Hills, Gray Hills, Piñon Ridge, &c., the position of each of which is shown upon the accompanying map.

DRAINAGE.

The greater part of the drainage of this district is effected by both the White and Yampa Rivers, in approximately equal proportion, but a large part of the permanent water of both these rivers is derived from the mountain region that lies beyond the district to the eastward. Green River cuts across the northwestern portion of the district, but as it traverses deep cañons in the Uinta Mountains along a part of that portion of its course, it receives very little addition to its waters there at any time of the year except what reaches it by the Yampa. Below the cañons, however, a few minor drainages reach Green River from the east side; and Ashley's and Brush Creeks empty into it from the west side.

The water-shed which divides the drainage between the White and Yampa Rivers consists of an irregular and somewhat tortuous line of hills, generally recognizable as a water-shed crest when seen from other elevations at a distance. The eastern part of this water-shed lies along the crest of the Danforth Hills, and is deflected so that it has there an almost due southeast and northwest trend, the eastern end of the district being almost wholly drained into the Yampa. The western portion of the water-shed, comprising the greater part of its length, has an approximately due east and west course. Its western terminus is upon the western end of Yampa Plateau, a large, broad mountain mass, which, as already explained, lies adjoining and is accessory to the great Uinta Uplift. The course of the water-shed upon the plateau is in some places within four or five miles of the Yampa River, which in this part of its course runs in a deep, narrow cañon. The relation of these drainage-lines and their water-sheds to the displacements of the strata in this region will be discussed under appropriate heads upon subsequent pages.

That portion of this district which lies between the two great mountain systems before named is more or less deeply cut by drainage-channels, leaving between them many elevations that are quite worthy of the name of mountains. The region embracing this district lies far within the limits of that great portion of the United States domain in which the annual rain-fall is insufficient for the purposes of agriculture. In consequence of this dryness of the climate, the drainage-valleys and ravines just referred to, which lead into the rivers, are with few exceptions dry during a great part of the year. These drainage-channels, which for convenience of description are called "dry drainage-channels," all show marks of an abundant and strong flow of water and of great and rapid denudation of the surface that is drained by them during the wet season of the year. A stranger, not familiar with the meteorological conditions prevailing in this region, travelling through it in the summer, would be impressed with the belief that the country was formerly a well-watered one, a land of a multitude of flowing streams which, for some cause not now apparent, had suddenly and permanently ceased to flow, and that in consequence the land had recently changed to a dry and barren one.

The present surface features of the district are almost wholly due to two principal causes, namely, elevation and consequent flexion and

*So named in honor of Rev. E. H. Danforth, Indian agent at the White River agency.

other displacements of the strata; and both simultaneous and subsequent subaërial denudation of the strata thus elevated. The latter process has produced what may with propriety be called the drainage features of the region. These are really the most conspicuous features of all, for the elevated portions of the great flexures have been mostly removed by the erosion just referred to. A part of the drainage of this district, like a large part of that of the whole great region within which it is located, is antecedent.* That is, it was evidently established before the principal displacements, including the great flexures, were produced. This view of the subject implies that the flexures were produced very slowly, and that before the strata began to bend the streams were already established upon the surface, and traversed the future sites of the flexures at various angles; and furthermore, that the streams continued to retain their original positions by a constant erosion, equivalent in amount with the elevation that was in progress. I am not unaware of the weighty objections that may be urged against this theory, but it seems to accord with the greatest number and most important of known facts.

It is a most remarkable fact that during this elevation of the strata the streams seem to have been very little influenced in or changed from their courses by either the favorable or unfavorable conditions for erosion of the strata themselves; mountain masses of quartzite not forcing a divergence, nor the softest strata inducing a departure from their predetermined courses. So far as my observation has yet extended, it is those channels only or mainly which have a greater or less flow of perennial water that are referable to the category of antecedent drainage. On the other hand, the present location of the dry drainage-channels of the region, as well as the unequal depth and extent to which the erosion has reached in them and upon the surface they drain, is largely due to the difference in the lithological characteristics of the strata out of which the surface features have been carved, but modified and controlled by the displacements which the strata have been subjected to. In other words, this part of the drainage system is mainly subsequent to or consequent upon the great movements that have resulted in the present displacements of the strata. This "consequent" drainage, although consisting mainly of those numerous minor branches which are dry during a part of the year, has produced present physical features that are scarcely less conspicuous than those which have been produced by all other causes; for by its agency almost all the immense erosion and degradation which the region has suffered has been accomplished, while the principal streams have served as vehicles for the transportation of the material thus removed from the surface.

PARKS AND BASINS.

The terms "park" and "basin," as names of geographical features, have been variously and somewhat loosely used by different writers. Finding it necessary to use them in this report for purposes of descripinto, I shall apply the term "park" only to those expansions of the river-valleys that contain more or less broad spaces of comparatively level land, a part of which is susceptible of cultivation by irrigation, and

* This explanation of the relation that the river-valleys of the great Rocky Mountain region generally hold to the displacements that the strata have suffered, by assuming that the displacements took place after the rivers were established, without material change in the course of the rivers, was first suggested by Dr. Hayden in the American Journal of Science and Arts for May, 1862, and afterward in his Report for 1872, page 85. The subject was afterward well elaborated by Professor Powell in his reports.

which are surrounded by such hills or high lands as usually border the valleys. The term "basin" I shall use for similarly excavated or hollowed spaces in the general surface of the country through which no river or perennial stream flows by which its lands may be irrigated. The basin has been produced by the erosion of the dry drainage-channels, while the park has been excavated mainly through the agency of a perennial stream. Parks, then, being really portions of the valleys, will be described in that connection, but the basins of the district will be separately considered, mainly with reference to their relation to the structural geology of the district. All the parks of this district are small, and their importance lies only in the facts that their relation to the structural geology is similar to that which the basins hold, and that they contain far the greater part of the tillable land of the region.

Midland Basin.—This basin is comparatively small, but a separate description of it is given because of the important relation it bears to the structural geology of its neighborhood. It lies near the middle of the district, and nearer to the southern than to the northern border. Its boundaries may be designated in general terms as follows: Piñon Ridge borders it upon the east; the hogbacks of the Midland Flexure upon the south; the eastern end of the Midland Ridge, in part, on the west; and its northern boundary is indistinctly defined by the broad ridge which forms the water-shed between the Yampa and White Rivers, separating Midland Basin from Lily's Park, and is continuous with the western portion of the Danforth Hills. It occupies a part of the broad anticlinal axis of the flexure that has brought up the great mass of Triassic strata which constitutes Midland Ridge and also the Fox Hills, and Laramie strata that constitute Piñon Ridge. The same flexure has, of course, brought up the sandy shales and clays of the Colorado Group, out of which the basin has been mostly excavated. Southwestwardly this basin is continuous, with a broad dry valley extending far, but gradually narrowing, to the westward, which valley, like the basin, is mostly excavated out of the shales of the Colorado Group. The surface of the basin has considerable irregularity, but is free from hills of any considerable height. Its drainage all passes into White River through a gap in the hogbacks of Midland Flexure, just west of the eastern end of Piñon Ridge.

Coyote Basin.—Unlike the other basins of this district, Coyote Basin occupies a broad synclinal instead of an anticlinal; also, it is mostly excavated out of the bad-land strata of the Wasatch Group instead of out of the soft strata of the Colorado Group as the others are. With perhaps the exception of the Bridger and Uinta groups, the Wasatch and Colorado groups are constituted of softer material than any others in this region, although in a portion of the district the Wasatch Group is in part a firm sandstone. When the conditions were made favorable by the flexures that all the strata of the region have suffered, those of the two last-named groups have yielded more readily to erosion than those with which they are associated. Hence the basins have been excavated out of these yielding strata only. Coyote Basin is bounded easterly by the concave sweep formed by the Gray Hills and Citadel Plateau; on the north, in part by Citadel Plateau and in part by the broad ridge that forms the water-shed between the White and Yampa Rivers and separates Coyote Basin from Axial Basin; on the west by Piñon Ridge and the high land that connects it with the water-shed ridge before referred to. On the south this basin is, in part, continuous with the valley of White River, with which it communicates and into which river it is drained. Its surface is an irregular, desolate bad-land area, traversed by numer-

ous drainage-channels, some of which are quite large; but even these are nearly or quite without water in summer. The synclinal within which this basin lies is partially surrounded by the great bend of the Midland Flexure which is represented on the geological map, and is also described in a following portion of this report.

Axial Basin.—This basin occupies a great anticlinal axis, which is the eastward prolongation of the vanishing axial flexure of the Uinta Mountain uplift. It is so long and narrow that the term "basin" does not apply to it with strict accuracy, but the use of such a term in this connection is not likely to be misunderstood. It extends from Junction Mountain nearly to the eastern border of the district, and is divided into two portions by Yampa Mountain, which is a sharp upthrust of Paleozoic rocks. Junction Mountain is a precisely similar upthrust of Paleozoic rocks, and it also occupies a similar position upon the Uinta axis, at the west end of the basin. Indeed it separates that portion of the basin which has been called Lily's Park from the main portion, in the same manner as, but less completely than, Yampa Mountain has divided that basin into two parts further to the eastward.

The boundaries of the eastern portion of the basin, that which lies east of Yampa Mountain, are more clearly definable than those of the western portion are, because they consist mostly of escarpment bluffs. This eastern portion of Axial Basin is bounded on the west by Yampa Mountain; on both the north and the south sides by escarpments of Fox Hills strata, and it ends eastwardly by a gradual rise of the whole land to the White River Plateau. The whole of this eastern portion of the basin was primarily eroded out of the shales of the Colorado Group, but for a distance of about four miles east of Yampa Mountain the surface is covered by the friable strata of the Uinta Group. Upon the top of a hill about three miles east of the eastern border of this deposit of the Uinta Group rest some of the strata of the base of the Fox Hills Group, but with these exceptions all the surface of the basin is occupied by the shales of the Colorado Group, except where these are obscured by soil, *débris*, or scattered drift. The Yampa River passes through only the northwestern corner of this part of Axial Basin, but, viewing the region topographically, the most natural course for that river to run would seem to be through the whole length of the basin, instead of cutting, as it has done, through the elevated land that borders the basin on the north, and which is composed of the comparatively hard sandstones of the Fox Hills and Laramie groups. This eastern portion of the basin is drained by the upper branches of Milk Creek, and a few other drainage-channels, which are mostly dry during a part of the year.

The boundaries of the western portion of Axial Basin are much less clearly definable than those of the eastern portion. In general terms it may be said to be bounded as follows: On the east by Yampa Mountain; on the south by the water-shed ridge between the Yampa and White Rivers; on the west by Junction Mountain, in part, and in part by Lily's Park. It is continuous with Snake River Valley to the northwestward, and on the north it blends, by a gradual rise, with the high lands that lie between the valleys of the Snake and Yampa Rivers. The western portion of the basin is, therefore, much wider than the eastern portion, and a very large part of it lies beyond the northern boundary of this district. The portion that lies within the district has, like the eastern portion, been primarily excavated out of the shales of the Colorado Group, but its surface is now occupied in very large part by the friable strata of the Uinta Group, through which, here and there, the underlying Colorado shales appear. Resting upon the Uinta deposit

is the scattered drift so common in a large part of this region. It reaches considerable thickness upon the higher surface of the basin, and also constitutes a large proportion of the bulk of the water-shed ridge before referred to. Yampa River traverses this part of the basin from east to west, and it might, therefore, with some propriety, be designated as a large park. But its basin-like character constitutes a greater and more conspicuous feature than any of the other similar excavations in the vicinity, especially as it occupies the lowest ground between the eastern end of the Uinta chain and the mountains that lie to the eastward of this district. Other features of both portions of Axial Basin will be referred to in the description of the valley of Yampa River.

Red Rock Basin.—This basin is located adjacent to the northwestern portion of Yampa Plateau, and near the confluence of Yampa River with the Green. Midland and Axial Basins have been eroded out of soft strata that rest upon comparatively gentle anticlinal axes; and Coyote Basin has been excavated by erosion out of other soft strata that rest in an equally gentle synclinal. But Red Rock Basin differs materially from those in the character and condition of its foundation, for it really consists of a very deep synclinal flexure of the hard strata of Carboniferous age, from which the somewhat softer, but comparatively firm Triassic strata have been removed by denudation, except at the bottom of the flexure, which is the bottom of the basin, where Triassic strata still remain. It is the southern side of this great synclinal that I have called the Yampa Flexure, and which synclinal separates the main Uinta, from the Plateau Uplift. This great synclinal flexure reaches its maximum depth at the west end of Red Rock Basin, where it ends abruptly against a mountain mass that projects northwardly from Yampa Plateau, by a north and south fault of about 2,000 feet downthrow; the depth of the basin below the northern border of Yampa Plateau being also about 2,000 feet. From this fault, the basin proper extends eastward five or six miles, when it becomes immediately narrower and gradually shallower, and thence extends eastward as a long narrow synclinal valley until it is lost among the hills at the eastern end of the Plateau Uplift. This valley and the deep basin with which it is continuous would seem to be a much more natural place for Yampa River to flow in than the one it has chosen, and which will be presently described, if it were not for the theory already explained that the streams are older than the flexures of the strata. The breadth of Red Rock Basin is about the same as its length. Its depth is so great that from the southern brim, the bottom looks comparatively plain, but it is really traversed by deep gorges that are cut in the red Triassic strata there, between which gorges the surface is rough and hilly.

VALLEYS

The descriptions immediately following are of the river—valleys as surface features. Their relations to the displacements of the strata over which the rivers flow will be discussed in a subsequent chapter. The parks being only portions of the valleys, the description of each of these will be included with that of the valley to which it belongs.

WHITE RIVER VALLEY.—White River, which in summer is a rapid stream of clear, cold water, rises by numerous small branches among the gorges and ravines of White River Plateau, all of which have their confluence with the main stream before it enters this district on its westward course. The bed of the river is almost everywhere strewn with drift-pebbles, and its banks are usually easy of approach, except where they

are obstructed by a thick growth of bushes. The valley varies in breadth, widening in some places to form the parks before mentioned, while in other places it is narrowed to a cañon, especially where the Green River Group occupies both sides of the river.

Agency Park.—Just above White River Indian agency the river cuts through the sandstone strata of the Dakota Group, which there dip to the northward and norhtwestward at a considerable angle. The dip, however, soon diminishes, so that for a space of several miles below the soft strata of the Colorado Group occupy the surface. Out of these strata Agency Park has been excavated, a portion of them still occupying its surface; the upper layers of the Dakota Group appearing within the park only at one locality, which is on the right bank of the river, near the middle of the park. This park is bounded on the north by a line of escarpment bluffs of the Fox Hills Group; on the east and south by hills of Cretaceous strata that lie at the western foot of the White River Plateau; and on the west by the Grand Hogback, which is composed of the upturned strata of the Fox Hills and Laramie Groups and separates Agency, from Powell's Park.

Besides several dry drainage-channels that traverse Agency Park to White River, there is one brook of perennial water. This rises in the hills to the eastward, and flows through the park two or three miles and empties into the river upon its right bank. Only a small proportion of the surface of any of the parks lies within reach of irrigating-water from the rivers that run through them, but, in consequence of the somewhat rapid fall of White River, a considerable area within the limits of Agency Park lies within reach of water that may be conducted in irrigating-ditches. Besides the water that may be thus taken from the river for irrigating purposes, the brook before referred to may also be made to furnish a small but, under the circumstances, valuable addition. There are some broad level spaces within the limits of the park, the surfaces of which are at various heights, a hundred feet or more, above the level of the river, that cannot be reached by irrigating-water from it, although they constitute a part of the park surface proper. These have somewhat the appearance of morainal benches, especially as they are usually more or less thickly strewn with drift-pebbles; but they are composed of the undisturbed strata out of which the park has been excavated. They doubtless represent periodical base-levels of erosion that were successively reached during the excavation of the valley, for they are of various heights above the level of the river and are common in all the broader portions of all the river-valleys of this region.

Powell's Park.—This park lies immediately west of Agency Park, with which it is connected by a gap in the Grand Hogback, through which White River flows. Its name is given in commemoration of the fact that Professor J. W. Powell and his party spent a winter here during his early exploration of this region. It is excavated out of the bad-land strata of the Wasatch Group which flank the Grand Hogback, and pass by a monoclinal flexure beneath the hills which border it to the westward, and which are composed of Green River strata. This park is only four or five miles wide from east to west; but as it communicates with a long dry drainage-valley that extends to the northward, and also a similar but smaller one that extends to the southward, its length north and south is great compared with its width, although its boundaries are somewhat indefinite. The greater portion of the irrigable land of the park lies on the north side of the river, and consequently within the limits of this district. It is Hogback Valley that is continuous with that portion of Powell's Park which lies within this district, the drainage of which

rises at the north side of Gray Hills and courses along the flank of the hogbacks of Midland Flexure and thence parallel with the Grand Hogback to White River. This drainage carries a large amount of water in the wet season, but it becomes entirely dry in summer.

Below Powell's Park the bluffs of the Green River Group come near to White River almost all the way to its confluence with the Green, so that between Powell's Park and the western side of Raven Park the greater portion of the width of the valley is upon the northern side of the river. Between Powell's Park and Coyote Basin the valley has considerable width on the northern side, and at several places there are considerable areas of irrigable land.

Raven Park.—A comparatively small uplift, which is separate from, but accessory to, the Uinta Uplifts, crosses the valley of White River at a point southward from Midland Ridge, where it has brought up to the surface the shales of the Colorado Group; and out of these shales Raven Park has been excavated. The park lies mainly upon the north side of the river; and since the Raven Park Uplift has a quaquaversal dip, the park is wholly surrounded by an escarpment of Fox Hills strata. The park is a small one; the river traversing its southern portion, a comparatively large proportion of its surface may be reached by water from irrigating-ditches leading from the river above its upper limit. Raven Park, like the others before described, and like many other portions of the valley, contains within its limits some of those broad benches or table-lands that have been before mentioned. They are above the reach of irrigating-waters and occupy a large portion of the surface of this park. Aside from the action of White River, the excavation of Raven Park has been mainly accomplished by an extensive dry drainage-creek that has its rise many miles to the northward, upon the slopes of Midland Ridge. For a distance of several miles below Raven Park the river valley is moderately narrow, but still there are some level bottom-lands on each side of the stream. Below this, almost all the way to the western border of the district, the river runs in an almost continuous, deep, narrow cañon, which it has excavated out of the strata of the Green River Group. The walls of this cañon are always steep and often perpendicular. In some places they are nearly a thousand feet in height above the river, and approach it so closely that it is always difficult, and for many miles impracticable to traverse it with a mule-train.

YAMPA RIVER VALLEY.—The Yampa has its origin by numerous mountain-brooks that rise among the granite gorges of the Park Range, and also among the Cretaceous rocks that flank that range on the west. Like White River, the Yampa is, in its upper portion, a clear, cold trout-stream, its bed being paved nearly all the way from its source to its mouth with smoothly-worn drift-pebbles. The Yampa has only two tributaries in this district, worthy of note, that carry perennial water. These are Williams Fork and Milk Creek, both of which will have further mention on subsequent pages.

Yampa Valley, like that of White River, has its parks and narrower spaces of low lands, but it is most remarkable for its cañons; not so much because it has cañons along its course as because that river seems from a superficial or topographical view to run where nature had placed especial obstacles in its way, apparently giving no heed to the favorable opportunities it seems to have had for pursuing a peaceful and easy course.

Between the eastern border of the district and the confluence of Williams Fork, the valley of the Yampa is a moderately broad one, the

northern side, especially, sloping gently up to the high lands, while the southern side is formed by the steeper slope of the long high ridge that constitutes the water-shed between the Yampa and Williams Fork. The dip of the strata, which are those of the Laramie Group, is to the northward, and this portion of the valley is therefore a monoclinal one. The widening of the valley here is doubtless due to the softer condition of the strata of that group in this vicinity than those of the same formation have farther southward and westward in this district. Much of the bottom-land of this part of the valley is irrigable and the rapid fall of the stream renders its irrigation easily practicable.

Near the confluence of Williams Fork, and for three or four miles below that point, the valley is narrowed by the encroachment of the bluffs, which are there composed of the strata of the Fox Hills and Laramie groups, those of the latter group being less soft there than they are farther up the valley, as before mentioned. In some places within these few miles of the narrowed valley, the sides are so steep as to give it the character of a cañon. This is particularly the case just above Cañon Park, where the river makes a very abrupt bend among the hills.

Cañon Park.—This is a very small park, and is chiefly noticeable because of its occurrence in a portion of the valley that is otherwise very narrow, the sides of which are steep and rocky; and also because of its relation to the geological structure of the neighborhood. The occurrence of this small park here is evidently due to the crossing of the river by a synclinal flexure or sag of the strata that has thrown the comparatively soft strata of the Laramie and Wasatch groups across the course of the valley, and out of these the park has been excavated, while the harder strata of the Fox Hills and lower portion of the Laramie Group form cañon-walls, or high, steep valley-sides above and below.

Between Cañon Park and the point where the river makes its exit through the bluffs into Axial Basin, which point is about six miles east of Yampa Mountain, the valley is tortuous and very narrow, being, in fact, a cañon along the greater part of the distance. The sides of the valley in this part of its course are so steep and high that, except at a few favorable places, access to the river from the high lands by a mule-train is difficult or impossible. This portion of the valley is excavated out of the strata of the Fox Hills and Laramie groups, those of the former group constituting, in great part, the south side, and those of the latter the north side of the valley.

Westward from the point where the river makes its exit through the bluffs into Axial Basin, it pursues a meandering course through the basin a distance that in a straight line is about six miles to Yampa Mountain. Here, instead of passing into the western portion of Axial Basin through the comparatively low space at the north side of Yampa Mountain, it cuts through the northern portion of that mountain by a deep cañon. After thus cutting through the mountain, the river meanders through the broad western portion of Axial Basin some 15 or 18 miles to Junction Mountain, through which it cuts its way by a still deeper and more precipitous cañon than the one by which it passes through Yampa Mountain. These two mountains are, as before stated, isolated upthrusts of Paleozoic rocks through surrounding Cretaceous strata that lie exposed in the Axial Basin, and are located directly upon the line of the axis of the Uinta Mountain chain. In neither case is there any superficially apparent reason why the river should not have run around, instead of through the mountain, for the surface around the base of each of them has only a comparatively slight elevation above the surface of the river, amounting, indeed, to only a fraction of the height of

the cañon-walls. Moreover, the surrounding rocks are among the softest that occur in the region, while those which form the mass of the mountains, and, conseqently, the cañon-walls, are the hardest; and it is not probable that these relative conditions have materially changed since the cañons were cut.

There is a considerable amount of irrigable land in the immediate vicinity of the river, in Axial Basin, both above and below Yampa Mountain; but a very large part of the surface of even the lower portion of the basin is above the reach of irrigating-waters.

Lily's Park.—This park lies between Junction Mountain and the eastern end of the Uinta Mountain chain, and is continuous with Axial Basin around both the northern and southern sides of Junction Mountain. It is here that Snake River has its confluence with the Yampa, the former river passing between Junction Mountain and the eastern end of the Uinta Uplift proper. After passing through Lily's Park a distance of six or seven miles, and receiving the influx of Snake River, Yampa River cuts through a line of hogbacks composed of Triassic strata, and then almost immediately enters Yampa Cañon, presently to be described. Lily's Park embraces quite a large area of land that may be irrigated from both the Yampa and Snake Rivers. Although small, it is doubtless the finest body of irrigable land within the district.

Yampa Cañon.—If it were not for the existence of the much greater and grander cañons of the Green and Colorado Rivers, Yampa Cañon would be worthy of renown for its great length and depth. This cañon begins at the eastern end of the Uinta Uplift and ends at Echo Park, where the Yampa has its confluence with Green River. The distance in a straight line from its eastern to its western end is about 25 miles, but its tortuous course makes its actual length much greater. Its general course is east and west and near the northern boundary-line of this district, but it passes to the north of that boundary-line a few miles before it reaches Green River. Its course is along the southern side of the south flexure of the axial portion of the great Uinta Uplift, and approximately parallel with the synclinal flexure between the Plateau and Uinta Uplifts that I have called the Yampa Flexure. Along the greater part of its length the cañon-walls are nearly or quite perpendicular, and often more than a thousand feet in height above the surface of the river.

As one stands upon the north side of Yampa Plateau, at the southern brink of Red Rock Basin, the bottom of which is about 2,000 feet beneath him, looking northward over and beyond the basin, upon the broad mountain slope that forms its high northern side, he gets only occasional glimpses of the position of the cañon as it meanders through that great rugged surface. So sharply perpendicular are the walls of the cañon on either side that the observer from the point mentioned not only sees it imperfectly, even when it is at all visible, but even when he has clambered over the rugged cliffs that rise around the cañon, he hardly realizes its presence in the neighborhood until he comes upon its verge and finds himself at a dizzy height above the rushing, roaring river at its bottom—so high that the river looks like a brooklet, and its roaring is changed to a faint murmer before it reaches the ear. These are among the grander and more impressive scenes which this region affords, and once witnessed will never be forgotten.

Williams Fork.—This stream, although a small one, is the principal tributary of the Yampa within this district. It rises among the ravines of the western side of White River Plateau and flows across the north-

ern corner of the district. Along this portion of its course it runs in a very narrow valley bordered by hills, the most of which are composed of strata of the Fox Hills Group. From the eastern border of the district to the confluence of a small branch that flows from near the eastern end of Axial Basin, its course is nearly parallel with and upon the north side of an anticlinal axis which produces upon its southern side a short, irregular line of hogbacks. From the confluence of the branch just mentioned to its own confluence with the Yampa, the course of Williams Fork is northward and through a deep narrow valley or cañon. This portion of its valley has been carved out of the strata of the Fox Hills Group, the river running almost directly upon the axis of a comparatively short anticlinal spur that extends northward from the place of blending of the Uinta and Park Range flexures.

Milk Creek.—This creek rises by several branches, some of them draining the northern side of Danforth Hills, but the main one rises near the eastern border of the district. It is insignificant in size, but it derives importance in this dry region from the fact that it contains perennial water. It is also worthy of especial notice because, although so small a stream, it affords a good example of antecedent drainage. The principal branch just referred to flows northwestwardly through the eastern end of the eastern portion of Axial Basin, but instead of pursuing its course westwardly down the basin to join the Yampa where that river enters it, the creek cuts through the bluffs that form the northern side of the basin and flows through a cañon carved out of the sandstones of the Fox Hills Group and joins the Yampa where that river is itself running in a similar cañon.

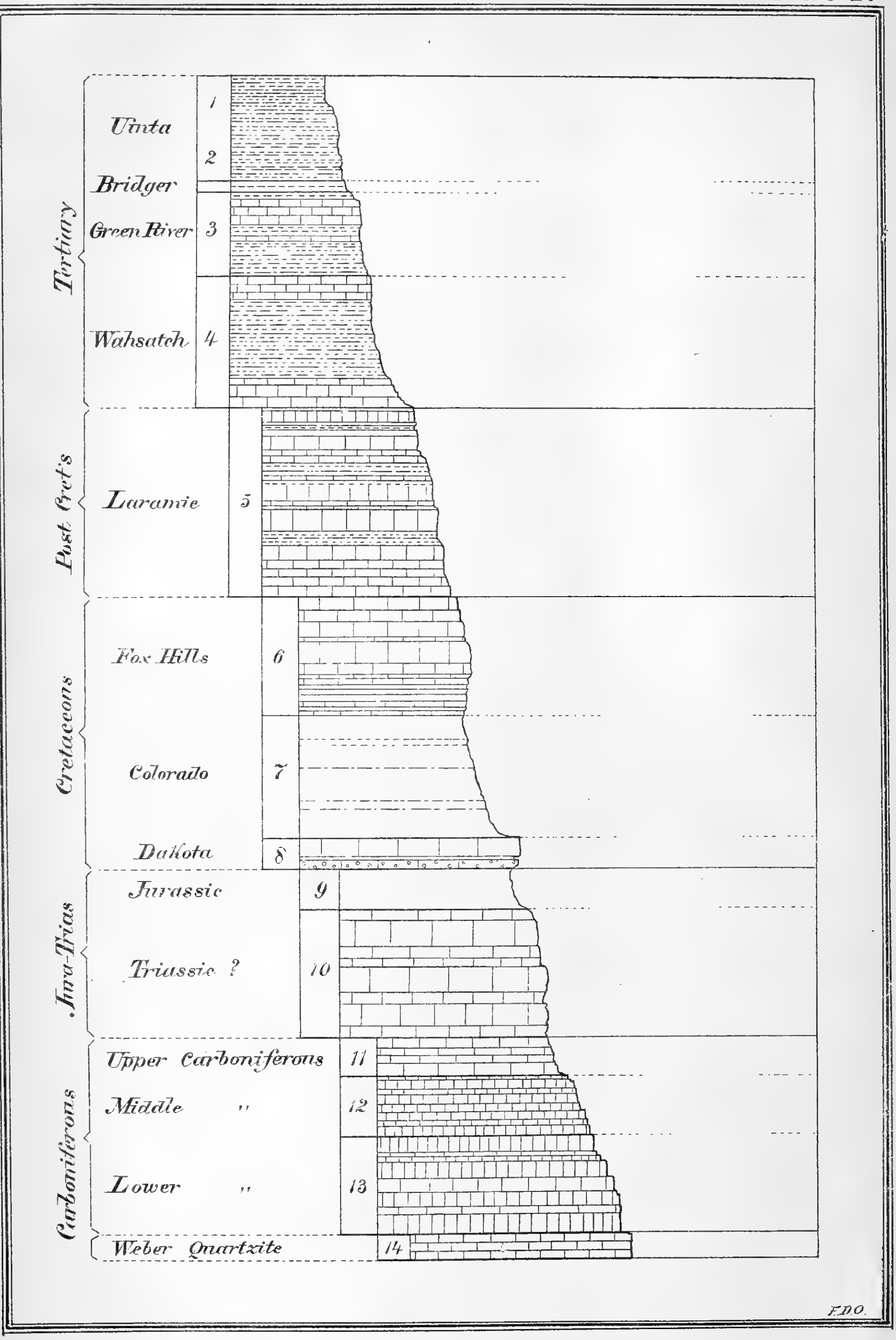
GREEN RIVER VALLEY.—Green River being the largest of those streams that unite to make up the great Colorado River of the West, is, properly speaking, the upper portion of that great river itself, and ought not to have received a separate name; but having received it, custom renders a change impracticable. It is into Green River that the whole drainage of this district passes, either directly or indirectly; but the river itself traverses only the northwestern corner of the district, entering it at Island Park and leaving it about midway of the western boundary. This portion of the river's course is quite tortuous, and it passes through one remarkable cañon, that of Split Mountain; but below this it passes through a broad open valley.

Island Park lies in the sag or dipping synclinal between Split Mountain and the main fold of the Uinta Uplift, and is thus bounded by high mountains on all except the western side. The park may be said to contain about ten square miles, but the amount of irrigable land within its limits is very much less; still, there is sufficient for the purposes of a small farming neighborhood, whenever it may be desired by settlers. The river here divides into several channels, and, quickly uniting, several small islands are formed, from which the park has received its name, and which add a feature of beauty to that small, secluded district.

Split Mountain Cañon.—As Green River makes its exit from one of its great cañons through the Uinta Mountains immediately upon entering Island Park, so it enters another great cañon, that of Split Mountain, immediately upon leaving the park. Split Mountain, as has already been shown, is a large mountain spur from the western end of Yampa Plateau, and it has received this name because it is cleft entirely through, and from top to base, by the cañon. The walls of the cañon are everywhere precipitous and in large part perpendicular, and are composed of Carboniferous limestones and sandstones. Its length is

upward of six miles, and the maximum height of its walls is nearly 3,000 feet. The view from the top of Split Mountain, upon the western verge of the cañon, is impressive in the extreme. The rushing river, more than half a mile beneath the observer's feet, appears like a babbling brook; and, although securely poised, many minutes elapse before he can command his nerves to sufficient composure for a calm survey of the terrible chasm. Immediately to the north of this point of observation lies the main range of Uinta Mountains, and to the east the broad Yampa Plateau. A broad expanse of lower lands stretches out to the southward and westward, upon the surface of which the structural geology of the region is shown with all the distinctness of a well-drawn geological map, so slightly are the strata of the formations obscured by vegetation, soil, or *débris*, and so vivid are the various colors of the rocks which compose them.

WONSITZ VALLEY.—The broad portion of the valley of Green River, which lies adjacent to this district, has been called Wonsitz Valley by Professor Powell. Although, when viewed from the adjacent mountains, its surface appears to be only slightly elevated above the river, it is nevertheless true that comparatively little of its surface is within reach of irrigating-waters. The greater part of the surface that is thus irrigable lies upon the west side of the river and beyond the limits of this district; but still many valuable farms might be established within its limits and irrigated from Green River.



General Section in the Yampa District.

CHAPTER III.

CLASSIFICATION, DESCRIPTION, AND DISCUSSION OF THE GROUPS OF STRATA.

The formations of this district present essentially an unbroken series from the Weber Quartzite, which lies immediately beneath the Carboniferous series, but is itself probably of older Paleozoic age, to the Uinta Group, which is the latest of the fresh-water Tertiary deposits of that region, inclusive.

The accompanying illustration, Fig. —, is intended to represent in their order a general section of these groups of strata, as they are developed or exposed in this district, to which area alone the thickness assigned to each is intended to apply. Following this illustration is a brief description of each of the groups represented by it, which is intended for more immediate reference in connection with the figure; but more detailed descriptions of the groups will appear where they are discussed on following pages.

EXPLANATION OF THE SECTION. *Fig.* 1.

No. 1. *Uinta Group.*—Fine and coarse-grained friable sandstones, with intermixed gravel in some places, forming a conglomerate; distinctly or obscurely stratified; the materials composing the strata in some places nearly or quite incoherent. General aspect gray or dull brownish red. Unconformable by sequence upon the other Tertiary, and several of the older groups in the district. Thickness about 1,200 feet.

No. 2. *Bridger Group.*—Variegated; reddish, grayish, greenish, and purple bad-land sandstones. Thickness exposed in this district only about 100 feet.

No. 3. *Green River Group.*—Upper division consisting of irregularly-bedded sandstones, often concretionary, with occasional laminated carbonaceous layers. Lower division consisting of laminated sandy shales or thin-bedded sandstones. Sometimes finely laminated shales which are more or less calcareous, and occasional dark carbonaceous layers are interspersed. Maximum thickness of both divisions about 1,400 feet.

No. 4. *Wasatch Group.*—Alternating soft and harder sandstones at top and base, between which the greater part of the group is made up of soft variegated bad-land sandstones. These bad-land sandstones are generally somewhat softer in the eastern than in the western part of the district. Thickness about 2,000 feet.

No. 5. *Laramie Group.*—Sandstones; thinly bedded, or in some places more heavily bedded, and forming hogbacks at many of the flexures of that formation in the district. Color sometimes reddish-ferruginous, and sometimes of the usual dirty yellowish or grayish hue; variegated in places by carbonaceous layers, and beds of coal. Thickness about 3,500 feet, but in some places probably less.

No. 6. *Fox Hills Group.*—Sandstones, heavily or thinly bedded; or sandy shales. Often weathering so soft at the base of the group as to obscure any line of demarcation between it and the next beneath. Thickness about 1,800 feet.

No. 7. *Colorado Group.*—Dark-colored shales, clayey or sometimes quite sandy; with occasional thin layers of sandstone. Thickness about 2,000 feet in the eastern part of the district and much less in the western part.

No. 8. *Dakota Group.*—Yellowish or brownish rough sandstones above; irregularly bedded pebble conglomerate below; and between these there is usually a greater or less thickness of variegated sandstone. Thickness about 500 feet.

No. 9. *Jurassic.*—Variegated, soft, bad-land sandstones with some strata of more indurated sandstone, and usually from 10 to 15 feet in thickness of shaly, sandy, and calcareous, fossiliferous rock near its base. Thickness about 600 feet.

No. 10. *Triassic?*— Yellowish, obliquely-laminated firm sandstones above; yellowish, soft sandstones below, and between them a series of bright red or brownish red, more or less firm sandstones. Thickness about 2,000 feet.

No. 11. *Upper Carboniferous.*—Irregularly bedded, light-yellowish sandstones with

occasional calcareous layers, the sandstone layers often containing masses and nodules of chert. Thickness about 600 feet.

No. 12. *Middle Carboniferous.*—Compact, bluish fossiliferous limestone, heavily or thinly bedded, alternating in some places with strata that are sandy and ferruginous. Thickness about 1,000 feet.

No. 13. *Lower Carboniferous.*—Massive layers of limestone alternating with those of sandstone and sandy limestone; all more or less ferruginous, generally presenting a reddish-brown aspect; and all usually regularly bedded. Thickness about 1,500 feet.

No. 14. *Uinta sandstone.*—Massive or thinly bedded, brick-red or more usually brownish-red sandstones; usually hard and often quartzitic. Thickness, exposed in this district, only about 400 feet; but the group reaches a thickness of nearly or quite 15,000 feet in the Uinta Mountains only a few miles from this district.

The districts surrounding the one here reported upon have, within the last few years, been geologically surveyed by different persons. That which adjoins it on the west has been reported upon by Professor Powell in his "Geology of the Uinta Mountains." A geological map of the district which adjoins this one upon the north has been prepared by Mr. Clarence King during the progress of the United States Geological Survey of the Fortieth Parallel. Reports, to be published simultaneously with this, are in course of preparation by the other geologists of the United States Geological Survey of the Territories, on the other districts which adjoin this one. A few copies of Mr. King's map have been distributed to different persons and institutions in advance of a geological report which is no doubt intended to accompany it. An examination of this map shows that the author has, in the main, adopted the classification of the strata which he finds exposed in that district, which has long been in use by Dr. Hayden in his reports; but with certain modifications in some cases. As no text yet accompanies Mr. King's map, I am, in some cases, in doubt as to the intended limits of the respective groups of strata that are there named and represented by colors. Having, however, made some personal examination of a large part of the region represented by that map, I think I do not incorrectly represent its intent in the following table of general sections. A large proportion of the names of the different groups of strata which are used in this report are, by the custom of priority in such cases, adopted from Mr. King's map, which is regarded as having been published in November, 1875. Mr. King's name, "Laramie Group," although it is understood to embrace strata that have previously received other names in different parts of the great Rocky Mountain region, is retained because of its more comprehensive application as indicating a great period in geological history, which is epochally represented by the Fort Union, Judith River, Lignitic, and other series of beds.

Dr. Hayden's name, "Wasatch Group," has, however, priority of publication over Mr. King's name, "Vermilion Creek Group," and also over Professor Powell's name, "Bitter Creek Group," and I therefore adopt the first-mentioned name. I adopt the name "Weber Quartzite" of Mr. King for the great formation that Professor Powell has called the "Uinta Sandstone," but not being in possession of Mr. King's facts, I am not yet prepared to adopt his reference of it to the Carboniferous age. Although the typical locality of the Lodore Group, which Professor Powell represents as existing at the base of the Carboniferous series and above the Uinta Quartzite, is near the northern border of the district here reported on, it does not occur within its limits. Professor Powell's section alone, therefore, represents it in the table.

Although Mr. King has not upon his map recognized the deposit called "Brown's Park Group" by Professor Powell as separate from the Green River Group, north of an east and west line that may be made to pass through the southern base of the great Uinta fold, a careful comparison

of those deposits on both sides of the Uinta Mountains has left no doubt on my mind of their identity. I therefore adopt Mr. King's name "Uinta Group," instead of Professor Powell's name "Brown's Park Group."

While adopting the name "Colorado Group" of Mr. King, I, for paleontological reasons chiefly, so restrict its application as to include only what I understand to be equivalent with Nos. 2 and 3 of Meek and Hayden's original section, leaving the equivalent of No. 4 to be included with the strata of the Fox Hills Group, instead of with the Colorado Group, as Mr. King has done.

The following table of general sections, as may be seen at a glance, is designed to show the correlation of the different groups named by the several authors, as I understand them. The first column represents the section that was many years ago prepared by Messrs. Meek and Hayden for the Mesozoic rocks of the Upper Missouri River region; the second embraces the names of the Tertiary and Post-Cretaceous Groups of Wyoming, Colorado, and Utah that have, from time to time, been proposed by Dr. Hayden; the third has been compiled from Mr. King's map of the Green River Basin, that has already been referred to; the fourth is the classification proposed by Professor Powell in his Report on the Geology of the Uinta Mountains; and the fifth is the classification of the rocks of this district which I have adopted in this report.

*Table of correlated general sections.**

<table>
<tr><th></th><th>MEEK AND HAYDEN.</th><th>HAYDEN.</th><th>KING.</th><th>POWELL.</th><th>WHITE.</th><th></th></tr>
<tr><td rowspan="5">Tertiary.</td><td rowspan="4"></td><td>Pliocene.</td><td>Uinta.</td><td>Brown's Park.</td><td>Uinta.</td><td rowspan="4">Tertiary.</td></tr>
<tr><td>Bridger.</td><td>Bridger.</td><td>Bridger.</td><td>Bridger.</td></tr>
<tr><td>Green River.</td><td>Green River.</td><td>U. Green River.
L. Green River.</td><td>Green River.</td></tr>
<tr><td>Wasatch.</td><td>Vermilion Creek.</td><td>Bitter Creek.</td><td>Wasatch.</td></tr>
<tr><td>Lignitic.</td><td>Lignitic.</td><td>Laramie.</td><td>Point of Rocks.</td><td>Laramie.</td><td>†
Post
Cret.</td></tr>
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<tr><td>Triassic.</td><td>Triassic ?</td><td>Triassic.</td><td>Triassic ?</td><td>Triassic ?</td></tr>
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<tr><td rowspan="2">Weber Quartzite.</td><td>Lodore.</td><td rowspan="2">Weber Quartzite.</td></tr>
<tr><td></td><td></td><td></td><td>Uinta sandstone</td></tr>
</table>

*The right-hand narrow column is intended to indicate the higher groups of my own classification, while the corresponding left-hand one represents that of the other authors as I understand them.

† See discussion of the name "Post-Cretaceous," on a subsequent page.

The columns of this table are arranged in the order of time of their publication, beginning at the left. The horizontal arrangement of the spaces within which the names of the groups of strata are placed is intended to represent their correlation; while the spaces themselves represent simply approximate coördination, the relative breadth of each space having no reference to the relative thickness of each group.

THE SILURIAN SYSTEM.

No other strata than those of the Weber Quartzite in this district are referred to Silurian age; and, as has already been shown, this great formation has been only provisionally so referred.

THE WEBER QUARTZITE.

This formation is usually of a dull brick-red or reddish-brown color, and has a peculiar sombre aspect, especially as seen in the deep cañons that have been eroded through it in the Uinta Mountain region. The stratification is always distinct, the strata more or less regularly bedded; sometimes massive, sometimes in thin layers, and occasionally in the condition of sandy shales. Sometimes it is in the condition of a common, but firm, sandstone, the grains being distinctly definable; but oftener the grains are so compacted by partial metamorphism as to give the rock the character of a true quartzite. In its common sandstone condition it is almost always harder than the sandstones of the Carboniferous and Mesozoic groups of that region usually are. So far as I am aware, no fossils of any kind have ever been discovered in any part of this great formation; and its true geological age is therefore unknown.

Upon his map, before referred to, Mr. King assigns this group to the Carboniferous system.

Dr. Hayden, several years ago, suggested the Silurian age of this great group, as did also Professor Marsh, who visited the region afterward. With this judgment, I am disposed to agree; but as before intimated, its geological age cannot be definitely known without the aid of fossils. Professor Powell has suggested the Devonian age of the Weber Quartzite, in connection with his statement of the unconformity of the true Carboniferous strata upon it. With this statement as to its unconformity with the Carboniferous, I also agree; but according to my own observation the unconformity is usually so slight that it may easily be overlooked. Furthermore, at all observed places in this district, as well as within a large area outside of it, the strata of the Lower Carboniferous rest directly upon the Uinta sandstone, those of the Lodore Group being absent. The Lower Carboniferous strata are often so very like those of the Weber Quartzite in general aspect that a casual observer would be in danger of confounding one with the other, especially if the unconformity should be, as it generally is, slight or obscure.

There are two or three localities, just where some deep dry-drainage cañons open into Red Rock Basin at the north side of Yampa Plateau by cutting across the Yampa Flexure there, where some of the upper strata of the Weber Quartzite are probably exposed; but for reasons already stated I am not entirely satisfied on this point, and therefore refer those strata to the Lower Carboniferous.

Strata of this group are well exposed in the walls of the cañon by which the Yampa passes through Junction Mountain, and they are also largely exposed in the southern half of Yampa Mountain, which lies some fifteen miles to the eastward of Junction Mountain.

CARBONIFEROUS SYSTEM.

The peculiar characteristics of those groups of strata which are abundantly developed in the great Rocky Mountain region, and which have been, by all geologists who have examined them, referred to the Carboniferous age, leave no doubt as to the correctness of that reference. It is, however, true that the three great divisions of the system, the Subcarboniferous, Carboniferous or Coal-Measures, and Permian, which are recognized in Europe and also, in part at least, in the interior region of North America, are not recognizable as such in the western portion of the continent, with the possible exception of the Subcarboniferous division, as distinct from the remainder. There seems indeed to be no good reason why we should expect to find this to be the case, because the marking-off of a system of rocks into groups and formations, as well as the modifications of the then existing forms of life, the remains of which are now found to characterize those formations, was due to the then prevailing physical conditions, and their periodical changes, the former of which we have no reason to suppose could have been universal nor the latter simultaneous in different parts of the world. The coal-making condition, which was remarkably characteristic of the Carboniferous age in Europe and Eastern North America, seems not to have existed at all, or only in an exceedingly slight degree, in what is now the great Rocky Mountain region, during any part of this great geological age. During the whole of that age, the deposits there seem to have been wholly marine, and to have been largely formed in comparatively shallow waters.

The Carboniferous strata of that western region are, it is true, marked off into groups, but they are not marked off in the same manner that they are in Europe and Eastern North America; and there ought to be no strained effort made to require those of the latter regions to correspond with those of the former, for they are not separated from each other by similar faunal and floral differences. There seems to be very little reason to doubt that the whole of the Carboniferous age is represented by the deposits referred to in Western North America, although the types of fossils they contain are seldom if ever of such a character as to warrant their distinctive reference to either the Subcarboniferous, Carboniferous, or Permian periods of the age. On the contrary, the types that are relied upon in Europe, and also others that are similarly relied upon in the eastern portion of North America, to prove the Subcarboniferous age of the strata containing them, are here found intimately associated with an abundance of those forms that are equally characteristic of the Carboniferous or Coal-Measure period, and even with some of Permian type. Furthermore, the uppermost division of the Carboniferous strata in this far western region, which probably represents in *time* the Permian Group of Europe, has not, to my knowledge, been found to contain a single faunal type that is in any proper sense characteristic of the Permian period as distinct from the Middle or Coal-Measure period. Therefore, in this report at least, I shall make no attempt to refer any of the Carboniferous strata of this great region to either of the three divisions originally established for the system; but I shall regard all the groups that have been named in the foregoing sections and elsewhere in this report as purely stratigraphical divisions, and probably inseparable from each other on paleontological grounds. This statement will explain why so little reference is had to paleontological characteristics in the following account of the Carboniferous groups. It is proper to mention, however, that from somewhat restricted

exposures of strata at a very few points in Nevada, Colorado, and Idaho, collections of fossils have been made that are not only specifically different from those which are so widely distributed in the Carboniferous rocks of that great region, but they are in part specifically identical with some that are found only in the Subcarboniferous strata of the States of the Mississippi Valley. The first of the following groups mentioned, however, is not to be here regarded as distinctively Subcarboniferous, although it may be so in fact, so far as anything is known to the contrary.

THE LOWER CARBONIFEROUS GROUP.

In some parts of the great Rocky Mountain region other observers have made out satisfactory lithological distinctions between the Lower and Middle Carboniferous Groups; but within the limits of this district the line of demarcation is so indefinite that I was not able to do more than make out a general separation of the two groups. I nowhere found any well-marked line of separation, and there being, as before stated, no sufficient paleontological distinction between the two groups, very few characteristics can be named as separating them from each other.

The Lower Carboniferous Group in this district consists of a large proportion of compact limestone strata that are usually more or less fossiliferous, alternating with layers of sandstone that are also usually somewhat calcareous. In general aspect this formation is of an indefinite reddish-brown or ferruginous color, often like that of the Weber Quartzite. The strata of this group are well exposed along the northern border of the eastern half of the Yampa Plateau, and also in Junction Mountain, of which mountain it forms a large proportion. It is there seen resting upon the Weber Quartzite, and in turn underlying the Middle Carboniferous. In Yampa Mountain, which is largely composed of the Weber Quartzite, the Lower Carboniferous is not satisfactorily separable from the middle group.

THE MIDDLE CARBONIFEROUS GROUP.

In this district, as before stated, the Middle Carboniferous Group is separable from the Lower only in aspect, and by some general lithological characteristics. The greater proportion of the bluish-gray limestones which it contains gives it a lighter aspect than that of the Lower, and distinguishes it also from the sandy strata of the overlying Upper Carboniferous Group. It is more fossiliferous than either of the other two divisions of the Carboniferous system in this district; but in consequence of the compact and cherty character of the rock, the fossils are seldom well preserved. The limestones of this group, besides being cherty, are often unevenly bedded. As a rule, they lack those marly and carbonaceous or clayey layers of shale that so commonly separate the limestone layers of the equivalent of this group in the Mississippi Valley The Middle Carboniferous Group contains much the greater part of the region, and from which softer layers most of the fossils are there obtained. calcareous strata found in this district, the prevailing material being almost everywhere sandstone and sandy shales.

THE UPPER CARBONIFEROUS GROUP.

The Upper Carboniferous Group is quite clearly distinguishable from the lower. In this district it is almost wholly composed of a light, yellowish-gray sandstone, often cherty, and containing only a few calcareous layers.

Usually, the sandstone is irregularly bedded, sometimes massive, and oblique stratification is quite common. Fossils are rare in this group, but a few have been found in its upper strata, and those yet known are not such as to distinguish it clearly from the other two Carboniferous groups. It is this group that Mr. King has designated as Permo-Carboniferous on his map. According to my observations, it is only its superior position in relation to the other groups that would suggest such a designation, because the Carboniferous groups below it contain fossils that are as closely allied with the Permian of Europe as any that have yet been discovered in the strata of this upper one.

The strata of this group are exposed at the surface of much the greater part of the area that is occupied by those of Carboniferous age in this district. They cover nearly the whole surface of the western half of Yampa Plateau, and nearly all the rugged surface through which Yampa Cañon is cut, along the southeast flank of the Uinta Uplift, besides a narrow area along the whole length of the Fox Creek Flexure. Narrow bands of its upturned strata are also exposed around the bases of Junction and Yampa Mountains. It will thus be seen that all the Carboniferous strata of this district have been brought to view only by the Plateau and Uinta Uplifts, and by the two sharp Upthrusts of Junction and Yampa Mountains. The remarkable peculiarities of these uplifts and upthrusts will be explained in a subsequent chapter.

THE MESOZOIC AGE.

Strata of Mesozoic age cover a large part of the surface of this district, and apparently form an unbroken series, from the base of those strata that have usually been referred to the Triassic period, to the uppermost Cretaceous strata, inclusive. The strata that I have, but with some doubt, referred to the Triassic period, are everywhere in this district and the surrounding region conformable upon those of undoubted Carboniferous age. Therefore there *appears* to be no important physical break in the series, as found in this district, from the base of the Carboniferous to the top of the Cretaceous,* notwithstanding the fact that the Lower Cretaceous of Europe seems not to be represented in this, if in any, part of North America. Comparatively few fossils were collected from any of the Mesozoic strata of this district during its geological examination, but the facility for observation, as before explained, makes their identification unquestionable, even if no fossils at all were obtained from them.

TRIASSIC PERIOD.

The strata, widely distributed over a large part of the western portion of North America, that have until lately been referred with little or no doubt to the Triassic period, have generally been simply so referred without a distinctive name as to groups or formations, but some geologists have subdivided the series and given distinctive names to thedivisions thus formed. They have been called by some simply the Red-Beds; but Professor Powell recognized three separate divisions of the group under the names, in the ascending order, of "Shinarump," "Vermilion Cliff," and "White Cliff" groups. These three divisions are recognized among those strata in this district, but they are not thought to be there of sufficient importance to be regarded as separate groups, coördinate

* See also remarks concerning apparent unbroken continuity of deposition of Mesozoic and Cenozoic strata on a subsequent page.

with the other groups that are treated of in this report. Until lately, also, these strata have been generally regarded as unfossiliferous, with the exception of the existence here and there of considerable quantities of silicified exogenous wood; and they were referred to the Triassic period mainly in consequence of their position between the recognized Carboniferous and Jurassic strata. Serious doubts of the real Triassic age of the strata in question have lately been raised because of the discovery of fossils in the lower portion of the group that seem to be not merely similar to some that are found in the group above the one in question, and which all persons agree in referring to the Jurassic period, but they are apparently specifically identical.

Dr. Hayden, on page 11 of his Report on the Geology of Captain Raynolds's Exploration of the Yellowstone and Mississippi Rivers, made in 1860 and published in 1869, states that he found unmistakable Jurassic fossils near the base of this group.

In 1874, Mr. Edwin E. Howell collected for Professor Powel several species of invertebrate fossils from the lower portion of the division of this group in Southern Utah, some of which, at least, I regard as specifically identical with well known-species, until then found only in unquestionably Jurassic strata.* These facts seem to indicate, with comparatively little doubt, that all the Mesozoic strata of that portion of Western North America, below the Cretaceous, belong to one period only, and that the Jurassic. This opinion is, of course, based upon the invertebrate fossils before referred to alone, no vertebrates or plants having been found or examined by myself. If the specific identification of the invertebrate fossils before referred to should be fully verified, there is no sufficient evidence, so far as I am aware, of the existence of any Triassic strata, distinguishable as such by its invertebrate fossils, in any part of the great region east of the great Salt Lake Basin and south of the Union Pacific Railroad. This question, however, is of so important a character that notwithstanding the evidence in favor of adopting the view just indicated, I prefer to use the provisional classification already given in this chapter, until material shall have been collected for a more complete discussion of the question. It is especially desirable to collect as much material as possible for this discussion, because these strata and their equivalents are distributed over so large a portion of the North American continent, where their lithological characters are generally so uniform as to render the group recognizable at once from them alone. However, in view of the fact that the relative position of this great series of strata seems to justify its reference to the Triassic period, while all its yet known invertebrate fossils show an intimate relation with those of the accepted Jurassic strata, I shall adopt for present use the general or collective term, Jura-Trias, for these two earlier Mesozoic groups.

As shown in the description accompanying the figure of the general section of the rocks of this district, the divisions of this group are all sandstones, the middle one being very conspicuous in consequence of its bright-red color. The lower division is sometimes so very much like the sandstone of the Upper Carboniferous group that it is difficult to determine where the one ends and the other begins, but in this district the strata of the former are considerably softer than those of the latter. The exposures of the strata of the middle division are often gorgeous in appearance as seen in the distance, for they are often exposed in extensive escarpment faces. Remarkable and extensive exposures of these red strata are seen in the southern and eastern faces of the great Mid-

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*See Geology of the Uinta Mountains, pages 80 and 87.

land Ridge, extending, indeed, almost continuously from its eastern to its western end.

Besides entering largely into the bulk of the great Midland Ridge, the strata of this whole group form an almost continuous line of hogbacks around the eastern end of both the Uinta and Plateau Uplifts, the whole length of Midland Ridge, and thence continuously around the western bases of both Section Ridge and Split Mountain. They also occupy the bottom of Red Rock Basin; and small isolated exposures of the strata are to be seen near the bases of both Junction and Yampa Mountains.

The fact that the middle and upper divisions of this group are so often exposed in the faces of hogback and other escarpments is doubtless due to the softer and more yielding character of the lower division, which, becoming disintegrated more rapidly than the others, allows the superimposed strata to fall down, leaving precipitous escarpment faces of the remaining rock.

THE JURASSIC PERIOD.

In this district, a group of strata of the Jurassic period is found everywhere bordering the exposures that are doubtfully referred to the Triassic. They consist mainly of soft, greenish, grayish, reddish, and purple bad-land sandstones, with a few feet of sandy calcareous layers near the base, which contain the fossils that are characteristic of the group. Being soft, the strata of this group are often obscured by the *débris* resulting from their own disintegration, while the associated strata, both above and below them, being harder, resist disintegration, and are often conspicuously exposed as hogbacks or other escarpments. Sometimes, however, they appear in the lower portion of the face of a hogback or escarpment, being protected there from further disintegration by a cap of the harder strata of the lowest group of the Cretaceous period. The thickness of the group in this district being only about 600 feet, and being usually exposed by flexures of the strata, it occupies only a small portion of the surface. Its exposures are, indeed, mostly confined to narrow bands that appear among the upturned groups of strata that flank the principal uplifts in the district.

It will thus be seen that all the groups hitherto described, occur in the northwestern portion of the district alone, all having been upturned along the flanks of the Uinta and its accessory uplifts. The whole of this large portion of the district is therefore occupied by the rocks of older date than the Cretaceous period, largely by those of Carboniferous age. This space is, however, bordered by rocks of the Cretaceous period, which, together with those of the Tertiary, occupy the remainder of the district.

THE CRETACEOUS PERIOD.

The whole series of Cretaceous strata as they are known to geologists, in the great Rocky Mountain region, is represented in this district, as well as another series immediately above them, concerning the proper age of which, geologists are divided in opinion, and to which I have given the separate but provisional designation of Post-Cretaceous. Under this head those strata are discussed upon subsequent pages.

The original grouping of the Cretaceous strata, as they are found developed in the Upper Missouri River region, by Meek and Hayden, is shown in the table of correlated sections on page —. It is also there shown that late authors agree in modifying that original grouping for

the Cretaceous rocks of Wyoming, Colorado, and Utah, by uniting the equivalents of certain of those groups under one designation, while preserving essentially the main features of the original classification. There is comparatively little difficulty in recognizing among the Cretaceous strata of the regions mentioned, the principal features of the classification which was originally made by Meek and Hayden for those of the Upper Missouri River region. That which I have followed consists mainly in reducing the number of groups by placing together those that have the nearest paleontological affinities. I have thus placed the equivalents of the Fort Benton and Niobrara groups together under the name of Colorado Group; and those of the Fort Pierre and Fox Hills groups together under the single name of Fox Hills Group, leaving, as all others have done, the Dakota, as everywhere, a single, separate group. Such a grouping of the Cretaceous strata is not only quite sufficient for all required purposes within the region to which it is applied, but it is as natural as the original grouping is for the Upper Missouri River region. The modification I have adopted is, for this district at least, quite as natural, stratigraphically, as that proposed by Mr. King (who joins the equivalent of the Fort Pierre Group to that of the Niobrara and Fort Benton groups to make up the Colorado Group), but I find it more natural, paleontologically.

All the groups of strata that are referred to the Cretaceous period in this report are, within this district, not only strictly conformable with each other as regards their stratification, but I have never been able to fix upon a plane of demarcation between any of them with entire precision. The aspect of the strata throughout the vertical range of all three of these groups, is that of continuous sedimentation. The general characteristics by which the groups are separated from each other will be given under the head of each.

THE DAKOTA GROUP.

The strata of this group are exposed as a narrow band among the upturned strata that flank the uplifts in the northwestern portion of this district, and also as a small but somewhat broader exposure, which is found to cap a portion of Midland Ridge, as is shown upon the geological map accompanying this report, and also upon one of the sheets of the great atlas of Colorado, soon to be published.

A very small exposure is also to be seen near the southwestern flank of Yampa Mountain, and another small one, of somewhat greater extent than the last, in Agency Park, near the right bank of White River. The latter exposure is brought up by a slight flexure that is apparently the vanishing northern end of the Elk Mountain Uplift, the main elevation of which is far to the southward.

The general lithological characteristics of this group are somewhat variable in different portions of the great Rocky Mountain region, but this variability is not such as to prevent its ready identification wherever it is sufficiently exposed, even in very widely-separated localities. In this district the group reaches an aggregate thickness of between 500 and 600 feet, and consists of two divisions, which, in some places, are more clearly defined than in others. The lower portion, having a thickness of some 300 feet, consists of a dark-colored, coarse, silicious pebble-conglomerate, which is somewhat irregularly bedded and easily disintegrated. The upper portion, having a thickness of from 150 to 200 feet, consists of a yellowish or brownish, rough, heavy-bedded sandstone, between which and the conglomerate some variegated bad-land

sandstones usually exist. These bad-land sandstones are similar in color and general character to those of the Jurassic Group; and where the conglomerate member of the Dakota Group is not brought up to view with the upper portion, as is the case in Agency Park, the bad-land strata of this group may be easily mistaken for those of the Jurassic.

This group seldom furnishes invertebrate fossil remains of any kind, especially in this district and the adjoining region; but very important floral and vertebrate remains have been obtained from it east of the Rocky Mountains. Its lithological characteristics, as well as its stratigraphical position in relation to the other groups, leave no doubt, however, of its identity. Professor Powell reports the existence of coal in the Dakota Group at some localities in Utah, but I observed no indications of its existence among the strata of the group in this district.

THE COLORADO GROUP.

As already shown, the limits of the Colorado Group are restricted in this report so as to intentionally embrace only the equivalents of the Fort Benton and Niobrara groups of the Upper Missouri River section, established by Meek and Hayden, and it is also understood to be equivalent with the Sulphur Creek Group of Professor Powell, as thus restricted.

It is doubtless true that in some places the strata which are regarded as equivalent with those of the Fort Pierre Group of the Upper Missouri River section, accord more nearly in lithological characters with those beneath, than with those above them. Mr. Meek, who studied the paleontology of these groups so carefully, has shown in his works that while the paleontological affinities between the Fort Benton and Niobrara groups, and the Fort Pierre and Fox Hills groups, respectively, are very close they are comparatively very slight between the two former and two latter groups respectively. Although the grouping of the strata of all geological ages in the western part of North America has been largely done by the field geologist, mainly upon stratigraphical grounds, and much of it properly so done, no person will justly question the necessity of giving preference to paleontological evidence in the proper geological grouping of strata. It is for this reason that, while adopting the name "Colorado" for the group under discussion, as having priority over that of "Sulphur Creek," I restrict its application to the strata that I understand to be the equivalent of the latter, and also the equivalent of both the Fort Benton and Niobrara groups, instead of including under the name thus adopted, the equivalent of the Fort Pierre Group also, as Mr. King has done.

The Colorado Group is perhaps more persistent in the uniformity of its lithological characteristics over a great region than any of the other Cretaceous groups, with the possible exception of the Dakota Group. It consists largely of that indurated clayey material, more or less distinctly laminated, which geologists generally, but somewhat loosely, denominate "shales"; but occasional layers of sandstone, usually soft, are sometimes met with. The strata of this, compared with those of the associated groups, are easily eroded. Consequently they seldom appear in escarpment exposures; and the stratification of the group is very often much obscured by its own *débris*. The lower portion of the group is more clayey, less sandy, and darker colored than the upper, but both being disintegrated and eroded with almost equal facility, a distinct line of separation between the two portions is seldom or never observable.

The comparative ease with which the strata of this group are disin-

tegrated and eroded has produced a marked effect upon the topography of the region in which they exist. Where the strata are considerably flexed, the space occupied by those of this group is a hollow or valley between lines of hogbacks which are composed of the harder strata that belong above and beneath this group. But where the flexure is more gentle, and especially upon a broad anticlinal axis, the strata of this group are often so eroded as to form a basin or park, such as have been described in Chapter II.

Near the base of the Colorado Group there is almost always to be found a bed of dark, fissile shales, containing the remains of teliost fishes. This bed not only occurs at all places in this district where the base of the Colorado Group is exposed, but it is equally characteristic of the lower part of the group in the adjoining districts. Overlying the bed of shales containing the remains of teliost fishes, there is often to be found a bed of coal. The only place in this district that I observed this bed of coal is a couple of miles south of the west end of Lily's Park, and southward from Junction Mountain. It is there three or four feet in thickness.

In this district the strata of the Colorado Group occupy the surface of Agency and Raven Parks; of Midland Basin; of, at least the eastern half of, Axial Basin, and also a considerable space bordering the mountain uplifts of the northwestern portion of the district.

THE FOX HILLS GROUP.

In accordance with the modified classification of the Cretaceous strata adopted in this report, the Fox Hills Group includes not only the strata that are understood to be exactly equivalent with those of that group, as it was originally defined by Meek and Hayden, in the Upper Missouri River region, but also those that are equivalent with the Fort Pierre Group, as it was originally defined in that region. As already stated, Mr. King does not on his geological map include with the Fox Hills Group those strata that he, as well as all other geologists, regards as equivalent with the Fort Pierre Group; but he includes the latter in the Colorado Group, together with the equivalents of the Niobrara and Fort Benton Groups. In the eastern portion of this district, and also to a less extent in other portions, the strata that I regard as probably equivalent with the Fort Pierre Group are more readily eroded and disintegrated than are those which overlie them, and constitute there the upper portion of the Fox Hills Group. In this respect they more nearly resemble in general aspect the strata of the group beneath than those above them; but for paleontological reasons, as before stated, I include the equivalent strata of the Fort Pierre with those of the Fox Hills Group, designating the whole by the latter name alone, rather than place it with the Colorado Group, as Mr. King has done, apparently on lithological grounds.

The fossils obtained from the equivalents of the Fort Pierre and Fox Hills Groups are not only so similar as to ally them closely with each other, but many of the species range through the whole series of strata that are understood to represent both of these groups. It is probable that some of the fossils of the Colorado Group range up through the remainder of the Cretaceous series; but, so far as the fossils of that group are now known, they seem to be so generally restricted to its own limits as to give it quite definite paleontological characteristics, and to leave the Fox Hills Group quite as clearly characterized.

In the western portion of this district the lithological difference between the upper and lower portions of the Fox Hills Group is not so

clearly shown as it is in the eastern portion, but yet the lowest portion of this group is everywhere of such a character lithologically as to be not clearly separable from the upper part of the Colorado Group.

In a general way, the lower division of the Fox Hills Group, which is about 800 feet in thickness, may be defined as a series of thin-bedded sandstones and sandy shales, which are often so easily disintegrated as to become covered with *débris* resulting from their own disintegration. In some places, therefore, the strata of this lower division seldom present escarpment faces; but in other places, especially in the western portion of the district, it contains one or two massive strata of firm sandstone, near the top of the division, that form prominent features in all the exposures there of this portion of the group. The principal one of these massive strata is from 30 to 50 feet thick, and is especially conspicuous in escarpments, of which it forms the cap. Where this great massive stratum exists, those below it gradually pass into the soft strata of the Colorado Group, and the strata above it are also soft, and are in turn capped by another massive stratum; and upon these comes the remainder of the upper division. This description applies particularly to the strata in the vicinity of Raven Park.

Upon the lower division rest about 1,000 feet more or less of regularly-bedded ordinary sandstones which constitute the upper division, and which form hogbacks wherever the strata are considerably flexed, and present bold escarpments under other conditions of flexion and erosion. These last-named characteristics of the group are particularly observable in and around Agency Park and the eastern portion of Axial Basin.

Several carbonaceous horizons were observed in different parts of the district among the strata of this group, including both the upper and lower divisions, but comparatively little coal was discovered. Near the base of the group, however, a bed of coal, probably of workable thickness and quality, is to be found in some places.

The strata of this group occupy quite a large part of the surface of the district, and the upper strata enter into the composition of a large part of the various hogbacks and escarpments within its limits. They are exposed in the north and west borders of Agency Park, in all the borders of Raven Park, and in both the north and south as well as the east borders of the eastern portion of Axial Basin. They occupy that portion of the surface between Yampa River and Williams Fork which lies adjacent to the latter stream, constitute a large part of Piñon Ridge, and are upturned to view in the Midland Flexure from one end of the district to the other.

THE POST-CRETACEOUS PERIOD.

Resting conformably upon the Fox Hills Group there is another series of strata which differs materially from any of the preceding groups in the character of its invertebrate fossils, although the sedimentation which produced it appears to have been continuous and unbroken from those groups into and throughout the series under discussion. The thickness of this series of strata is greater than that of any of the Cretaceous groups proper that preceded it, reaching a maximum thickness in the district here reported upon of at least 3,500 feet. A few hundred feet, constituting the upper portion of this series in the valley of Bitter Creek, Wyoming, has been, by Professor Powell * and myself, separated

* See Geology of the Uinta Mountains, and Article XXV, Vol. III, Bull. U. S. Geol. Surv. Ter.

from the greater, lower portion of the series, and placed with the Wasatch Group above it. This was done because of an unconformity of the two portions in that district, and an entire conformity of that upper portion with the strata of the Wasatch Group above it, although the affinities of the fossils of that upper portion are with those that are found beneath, rather than with those of the Wasatch Group above. After a careful examination of the extensive exposures of this series of strata, as well as those of the Wasatch Group above it in this district, I have failed to discover any unconformity, such as exists in the valley of Bitter Creek. Therefore, the greatest unconformity that is now known to exist among any of the strata from the base of the Cretaceous to the top of what I here designate as the Post-Cretaceous, is found among the strata of the latter group, and not at its top. In this district and the region immediately adjoining it, whatever catastrophal or secular changes may have meanwhile taken place elsewhere, or even extending within its limits, sedimentation was evidently continuous and unbroken, not only through this series itself, but also into and through the whole Wasatch Group also.

The fact that this series passes insensibly into the Fox Hills Group below, and into the Wasatch Group above, renders it difficult to fix upon a stratigraphical plane of demarcation, either for its base or summit. I have therefore decided to regard this group as essentially a brackish-water one, referring all strata below, that contain any marine Cretaceous invertebrate forms, to the Fox Hills Group, beginning this series with those strata that contain brackish- and fresh-water forms, and ending it above with those strata in which the brackish-water forms finally cease. Thus defined, the whole series seems to form one natural paleontological group, as well as to be a sufficiently distinct stratigraphical one, for which I have adopted the name of Laramie Group of King.

My reasons for separating this group from the Cretaceous series, where it has been placed by Cope, King, and Powell, and for giving it the provisional designation of Post-Cretaceous, have been discussed by me in Article XXIV, Vol. III, No. 3, Bulletin of the United States Geological and Geographical Survey of the Territories, but they may be briefly repeated here. The flora of this group is understood to be wholly of Tertiary types, according to Professor Lesquereux. None of its invertebrate fossils are of distinctive Cretaceous types, although fossils of similar types are known to occur in Cretaceous as well as Tertiary strata. So far, then, as the flora and invertebrate fauna are concerned, there is nothing to indicate the Cretaceous age of the group. In fact, Invertebrate Paleontology is utterly silent upon the subject. On the contrary Professor Cope finds reptilian remains, even in the uppermost strata of the group, that he regards as of Cretaceous type. I believe that, upon the evidence of invertebrate paleontology, the Fox Hills Group is later than the latest Cretaceous strata of Europe; and I therefore regard the Laramie Group as occupying transitional ground between the well-marked Cretaceous and Tertiary groups, but this opinion is only tentatively held until further facts are obtained.

THE LARAMIE GROUP.

The relations of the Laramie Group to those immediately above and below it in the geological series, as well as its general characteristics, have been pointed out in the last paragraphs, and it now remains to speak of its characteristics as they are shown in this district and those adjoining it.

The Laramie Group, in a large part of Southern Wyoming and the

adjacent parts of Colorado and Utah, consists mainly of the ordinary indurated sandstones that so largely enter into the composition of the Cretaceous groups of that region, together with somewhat frequent beds of carbonaceous shales, and several beds of coal of greater or less importance. This description has also a good general application to the group, as it is developed in this district; but in the eastern part it consists very largely of a series of reddish-colored, usually thin-bedded sandstones, together with some shaly and carbonaceous beds. These peculiarities, however, gradually merge into the more common characteristics of the group to the westward. Besides many more or less distinct carbonaceous horizons, the group contains several beds of coal within this district. One of the best is near its base, and another near its top, with others between, that may, perhaps, be found to be of workable thickness.

The strata of the Laramie Group occupy a large space between the eastern portion of Axial Basin on the one side, and Agency Park and Hogback Valley on the other. It is brought to view along the whole length of both the Midland and Raven Ridge flexures, besides occupying considerable spaces to the northeastward and northwestward of Raven Park. It also occupies the larger part of the space between Williams Fork and Yampa River, within the district, as well as the most of that portion of it which lies north of the Yampa and between the mouth of Williams Fork and Yampa Mountain. For the more precise limits of the surface occupied by the strata of the group within the limits of this district see the geological map accompanying this report, and also that of the large atlas of Colorado, published by the Survey.

So far as known to me, the strata of all the Cretaceous groups of Western North America, beneath the horizon of the Laramie Group, are of marine origin, except a few local deposits in different portions of the series, which contain brackish- and fresh-water invertebrate forms. On the contrary, no exclusively marine invertebrate forms are known to have been obtained from the strata of the Laramie Group, as I have defined its limits in this report. The species of *Inoceramus* that have heretofore been reported from the lower strata of this group, I am now satisfied should be referred to the Fox Hills Group, the error of reference having been made in consequence of the absence of a distinct stratigraphical plane of demarcation between the groups. The comparative abundance of remains of land-plants in all the strata of the Laramie Group also indicates its separation from the open-sea deposits.

THE TERTIARY PERIOD.

In the great region that is now drained by the Green River there are three well-marked groups of strata, all conformable with each other, that come in their order above the Laramie Group, and which all agree in referring to the Tertiary period. These are the Wasatch, Green River, and Bridger Groups, named in the ascending order.

As already mentioned on a previous page, all the groups of the Cretaceous period, as they are developed in the great Rocky Mountain region, so far as I have been able to observe, or to obtain information of them, are strictly conformable upon each other. I have also shown that the Post-Cretaceous Group is strictly conformable upon the uppermost of the Cretaceous groups, although some unconformity is known to exist among the strata within the limits of the Post-Cretaceous Group (the Laramie Group), to the northward of this district. I have been equally unable to discover any unconformity between the strata of the

Laramie Group, which I have designated as Post-Cretaceous, and those of the Wasatch Group, the earliest of the Tertiary groups proper. Neither have I been able to discover any definite, stratigraphical plane of demarcation bewteen the two groups.

THE WASATCH GROUP.

In his annual report for 1870, Dr. Hayden proposed the name "Wasatch Group" for a series of strata that are extensively developed in Southern Wyoming and adjacent parts of Utah and Colorado. I regard the series of strata to which Mr. King has given the name "Vermilion Creek Group," and Professor Powell, that of "Bitter Creek Group," as geologically equivalent with the Wasatch Group of Dr. Hayden, and I therefore use that name in this report, in accordance with the recognized rule in such cases.

The Wasatch Group is the lowest of a series of three fresh-water Tertiary groups, all of which are intimately connected, not only by an evident continuity of sedimentation throughout, but also by the passage of a portion of the molluscan species from one group up into the next above. Not only were these three groups, aggregating more than a mile in thickness, evidently produced by uninterrupted sedimentation, but it seems equally evident that it was likewise uninterrupted between the Laramie and Wasatch epochs, although there was then a change from brackish to fresh waters, and a consequent change of all the species of invertebrates then inhabiting those waters.

The Wasatch Group in this district consists very largely of soft, variegated bad-land sandstones that reach a thickness of about 1,500 feet, together with from 100 to 300 feet of the ordinary indurated sandstones, alternating with bad-land material at the base, and a similar amount of similar material at top, the estimated aggregate thickness being about 2,000 feet. The lithological characteristics vary somewhat in different parts of the district, the middle portion sometimes losing its distinctive bad-land character, and the sandstones becoming more indurated, but they seldom become very hard.

The exposures of the Wasatch Group in this district are mostly confined to that portion of the surface occupied by the principal flexures of strata, the surfaces of Coyote Basin and Powell's Park being the broadest spaces occupied by those strata. They are upturned by the Midland, Grand Hogback, and Raven Ridge flexures, and are exposed in the valley of White River along a great part of the whole distance from Powell's Park to a point a few miles below Raven Park. Being composed of easily eroded materials, the strata of this group seldom produce any conspicuous features of the surface, except the valleys and basins that are eroded out of them, such as Powell's Park, Coyote Basin, Hogback Valley, and a part of White River Valley.

Very few fossils were obtained from the strata of the Wasatch Group in this district. Specimens of the genera *Viviparus*, *Goniobasis*, and *Unio* were obtained from strata near the top of the group in Raven Ridge, near the southwestern border of Raven Park. The same genera, and doubtless the same species, were found in a similar horizon in the valley of White River opposite Piñon Ridge, where also fragments of *Physa pleromatis* White, were obtained.

THE GREEN RIVER GROUP.

Resting immediately and conformably upon the Wasatch are the strata of the Green River Group. Although intimately connected with the former by continuous sedimentation and specific identity of mollus-

can species, they differ considerably from those of that group in general aspect, and in composition also. The group is, lithologically, at least, separable into two divisions, but they are not regarded as severally of co-ordinate value with the other recognized Tertiary groups. The lower division consists mainly of silicious and sandy shales, and laminated and thin-bedded sandstones, with, in some places, especially in the western part of this district, frequent layers of hard, dark-colored carbonaceous shales. In some places the strata are also quite calcareous, occasional layers being nearly pure, compact, finely-laminated limestone. Others of the calcareous layers are sometimes oölitic in texture. The general aspect of the strata as seen exposed at a distance is light gray.

The upper division consists mainly of sandstones that are coarser, as well as less thinly and distinctly bedded, than those of the lower division. In some parts it is shaly, and in others carbonaceous. Much of its sandstone is ferruginous in aspect, instead of having the gray tint that the lower division has. Sometimes certain beds of its sandstones are earthy and easily disintegrated, often leaving, weathered out of the mass, spherical concretions of hard sandstone that vary in size from a fraction of an inch to two or three feet in diameter. Other beds sometimes present buttress-like masses in the brow of bluffs, which form conspicuous and somewhat remarkable features in the landscape. Such features are very characteristic of this division in the bluffs of Green River in the vicinity of Green River City, Wyo., and, to a less extent, they also appear in the bluffs which border the cañon and valley of White River, in the southwest portion of this district.

The invertebrate fossils which this group affords are similar to those that are found in the fresh-water portion of the Wasatch Group, some of the species being identical, and indicate a purely fresh-water condition throughout. They are almost wholly molluscan, and belong to the branchiferous genera *Unio*, *Viviparus*, and *Goniobasis*, beside several genera of pulmonate gasteropods, including both the limnophile and geophile divisions. The Green River Group has become somewhat noted for the fossil fishes that have been discovered in its strata in Wyoming, and, like the Wasatch Group, it has at various localities also furnished considerable collections of fossil vertebrates and plants.

In this district, the Green River Group is well and characteristically developed, the lower division reaching a thickness of about nine hundred feet and the upper division about five hundred feet. The large hill-masses that lie between Hogback Valley and Powell's Park are composed of it, as are also those that form the bluffs of the south side of the valley of White River, from Powell's Park to the western boundary of the district, except that portion of them which forms the southern border of Raven Park. It also occupies a considerable space adjacent to White River, between Raven Park and the western boundary of the district, and also a narrower space along the southwestern side of Raven Ridge.

The strata of the lower division of the Green River Group differ considerably in lithological characters in different parts of this district. In the hills that lie between Hogback Valley and Powell's Park they are more largely composed of ordinary sandstones than is usual in this group, some of which constitute thick, heavy-bedded strata. In the southwestern part of the district the strata of this division are more finely laminated, and contain much more calcareous and carbonaceous material than elsewhere.

The principal flexures and other displacements of the strata of this

region doubtless took place after the deposition of the Green River Group, but in the district here reported on the strata of the whole group are, as a rule, nearly horizontal, or vary only a few degrees from the horizon. This is evidently due to the fact that they have been eroded from the spaces that are now occupied by the more abrupt flexures, which they doubtless once covered, but are now found to occupy only or mainly the comparatively undisturbed spaces on the dropped side of the flexures.

THE BRIDGER GROUP.

This is one of the more important of the groups among those that, in western North America, are referred to the Tertiary period, especially as regards the vertebrate remains that have been obtained from its strata. It is most fully and characteristically developed in the region known as the Green River Basin, north of the Uinta Mountains, only the southeastern portion of the formation, so far as it is now known, extending within the limits of this district. In its typical localities it is found resting conformably upon the Green River Group, into which it passes without a distinct plane of demarkation among the strata. Its molluscan fossil remains correspond closely with those of the Green River Group, some of the species being common to both, all indicating a purely fresh condition of the waters in which the strata of both groups were deposited. At the typical localities the group is composed in great part of soft, variegated, bad-land sandstones, a peculiar greenish color often predominating over the others, which are reddish, purple, bluish, and gray. Limestone strata, marly and clayey beds, and cherty layers are not uncommon, and grits and gravelly layers sometimes occur.

Strata of the Bridger Group are found to occupy only a comparatively minute portion of the surface in this district, the only locality at which they appear being in the valley of Red Bluff Wash, between Raven Ridge and White River, in the southwestern part of the district, where these strata rest upon those of the upper division of the Green River Group, and are covered in turn by those of the Uinta Group. The strata of the Bridger Group exposed there reach only about one hundred feet in thickness, and probably represent those near the base of the formation. The only fossils obtained from these strata were a few fragments of chelonian and mammalian bones.

THE UINTA GROUP.

Resting directly, but by unconformity of sequence, upon all the Tertiary and Cretaceous groups in the region surrounding the eastern end of the Uinta Mountain Range, is another Tertiary group that has received the name of "Uinta Group" from Mr. King, and "Brown's Park Group" from Professor Powell. It is possible that this group was deposited continuously, at least in part, with the Bridger Group, but at the places where the junction between the two groups has been seen in this region, there is an evident unconformity, both by displacement and erosion.

The group consists of fine and coarse sandstones, with frequent layers of gravel, and occasionally both cherty and calcareous layers occur. The sandstones are sometimes firm and regularly bedded, and sometimes soft and partaking of the character of bad-land material. The color varies from gray to dull reddish-brown, the former prevailing north of the Uinta Mountains and the latter south of them.

The only invertebrate fossils that are known to have been discovered in the strata of this group are some specimens of a *Physa*, very like a recent species. Therefore, invertebrate paleontology has furnished no

evidence of its assumed Tertiary age and lacustrine conditions of its deposition. Its fresh-water origin, however, seems unquestionable, because of its intra-continental position, its limited extent, and the fact that none but fresh-water deposits are known in this part of the continent that are of later date than the close of the Laramie period.

While the known unconformity of this group upon the other Tertiary groups, as well as upon the still older rocks, might, in the absence of other facts, be suggestive of its post-Tertiary age, the following facts seem to show that it cannot be of later date than Pliocene Tertiary, to which epoch Dr. Hayden, upon the occasion of his first visit to that region, referred it. In many places the strata still remain in a nearly horizontal position, but in others they have been considerably displaced, as, for example, by being flexed up against the flanks of the Uinta Mountains, and also in a similar manner against the Dry Mountains, northeastward from Brown's Park. This shows that, although much movement of displacement took place before the deposition of the Brown's Park strata, as shown by their unconformity with those of the older groups, a considerable amount of movement, even of mountain elevation, has taken place since their deposition. Besides this, a large proportion of the immense denudation which the strata of that region have suffered is known to have taken place since the deposition and partial displacement of the Brown's Park Group, because these strata are involved with the others in that denudation. Furthermore, a remarkably extensive outflow of basaltic trap, covering a large region which lies mainly to the eastward, but which formerly extended much within the limits of this district, took place after the deposition of the Uinta Group, and also after it had suffered displacement and erosion to some extent at least. This is known to be the case, because the trap is found resting upon the unevenly eroded surface of a portion of the Uinta Group at Fortification Butte. That portion occupies a higher level than does the principal portion of the group, at least within this district; and the trap rests unconformably upon the Laramie and Cretaceous strata in the immediate vicinity, as well as upon the Uinta strata, in such a manner as to show that little, if any, movement has taken place since the trap outflow. The denudation of the rocks of that region has been so great since the trap outflow that the latter rock has been removed from a large part of the surface it once occupied, leaving only here and there mere shreds of the once massive and extensive sheet upon the higher hills.

Water-worn fragments of this trap, together with those of other rocks, enter into the composition of the scattered drift of that region. This drift was probably contemporaneous with the great northern glacial drift, and is found not only in the valleys of that region, but also scattered upon the hills many hundred feet higher than the streams. These facts seem to be sufficient to prove that the Uinta Group cannot be of later date than Pliocene Tertiary, while its relations to the other Tertiary groups seem to show that it cannot be referred to an earlier epoch than the Miocene. But further evidence on this point is needed.

This group occupies that expansion of Green River Valley which is known as Brown's Park. From there it extends eastward and around the eastern end of the Uinta Uplift, except a few miles interruption of its continuity there, and thence extends westward along the southern base of the Uinta Mountains a large part of the length of the range. It extends northward from the eastern portion of the Uinta Mountains as far as Dry Mountains and Godiva Ridge. Remaining patches of it show that the formation formerly extended eastward as far as the foot-

hills of the Park Range. The relation which this group has to similar groups in different parts of that great western region remains for future investigation to determine. Its relation to those immediately associated with it is a matter of great interest, which will be much enhanced by any paleontological testimony that its strata may yet furnish.

In this district the Uinta Group occupies nearly the whole surface of the western portion of Axial Basin, comparatively small areas immediately east and immediately north of Yampa Mountain, and a considerable portion of the space between Junction Mountain and the eastern end of the Uinta Uplift, all of which spaces are in unbroken continuity. It also occupies quite a large space in the western part of the district, which is bordered, in a general way, by Raven Ridge, Red Bluff Wash, and the western boundary-line of the district, beyond which it is continued far to the westward. Throughout the whole of this last-mentioned space the strata of the group have that dull rusty-red aspect and partial bad-land character before mentioned, while to the eastward of the Uinta Range the general aspect of the group is gray.

ERUPTIVE ROCKS.

Besides the stratified rocks of this district, which have already been described, a few of igneous origin are found in the eastern portion These are remaining portions of a most remarkable outflow of dark colored vesicular bassaltic trap, which, after the close of the Tertiary period, took place in the region bordering upon the eastern portion of this district, extending also to the northward and southward. Much the larger part of this great outflow has evidently been removed by erosion so that only shreds of it remain where it once occupied the surface as a continuous sheet. Broken masses of this rock are scattered profusely upon nearly all the higher hills in the northeastern portion of the district, but upon only one point within its borders was it seen to occupy its original undisturbed position. Just beyond the border of the district to the eastward, however, especially upon the White River Plateau, it yet abundantly overspreads the stratified rocks upon which it was deposited at the time of the outflow. This trap-outflow is known to have taken place after the deposition of the Uinta Group because the trap is found to rest upon the latter at Fortification Butte, some six miles north of the northeast corner of this district. It is known to be of older date than the drift of that region, and also older than other Quaternary changes that have taken place there, because it, together with other rocks, has suffered such extensive erosion since its deposition, and because the drift-pebbles are in part composed of the trap.

Other outflows of similar rock have occurred at other localities in the Park Range, some of which were probably contemporaneous with this one, and it is probable also that this one was produced from more than one vent. The only vents I was able to observe, however, was one in the form of a dike, some eighteen miles north of the northeast corner of this district, and another at "Chimney Rock" in Egeria Park, in the mountains east of the district. This dike consists of a vertical wall about twenty feet wide and three or four miles long. The rock of the dikes is similar to that of the outspread trap, but is much less vesicular. Indeed, it was not often that any vesicles could be detected by the unassisted eye in the rock of the first-named dike, and these were flattened in the vertical plane of the dike itself. It seems to have been only in the horizontal portion of the outflow, where the pressure was at its minimum, that the vesicular character of the rock became most marked; and in some of the layers, for it sometimes has an indistinct appearance of stratification, the vesicular character is wanting.

CHAPTER IV.

DISPLACEMENTS.

This district possesses unusual geological interest, because it is the ground upon which displacements of the strata belonging to two different orographic systems, those of the Uinta and Park Range Mountains, meet and blend together. The district is so small, however, that it does not embrace within its limits a very considerable portion of either of these mountain systems. Some of the minor flexures, or the vanishing ends of more important ones, of the Park Range system, reach within the eastern border of the district; but the greater part of the displacements which the strata of the district have suffered belong to the Uinta system. The relation of these displacements to the Park Range system are not clearly perceivable until they are traced beyond the eastern and southern limits of the district here especially reported on; therefore the accompanying map is made to embrace considerable additional space beyond both its eastern and southern borders. The labors of the other geologists of the survey have made known the orographic characteristics of that portion of the Park Range that lies to the eastward and southeastward of this district; while those of Mr. King and Professor Powell have made us acquainted with the structure of the Uinta Range. The main displacements of these two systems being thus known, their relation to and connection with each other and with accessory flexures within this district may be easily traced upon the accompanying geological map.

The general plan of structure of the Uinta Uplift has been shown by Mr. King and Professor Powell to consist essentially of one great flexure of uplift, the axis of which is approximately east and west. The last-named geologist has shown that this great Axial Uplift of the Uinta Mountain system is distinctively characterized by an abrupt flexure of the strata, which is in some places a true fault, on each side of the great fold, and that between the two abrupt side bendings the anticlinal bending of the strata is comparatively slight. This peculiar form of folding of the flexures seems to be generic, so to speak, to the Uinta system, since it is found to characterize certain of the principal accessory flexures as well as the Yampa and Junction Mountain upthrusts, as will be explained in connection with their description on following pages.

The Uinta system ends, as a mountain-range, upon and about mid-length of the northern border of this district; but the Axial Flexure, abruptly and very greatly diminished in scope, continues eastward from the end of the mountain-range through the strata of the eastern portion of the district and blends with certain flexures of the Park Range, as will be explained on following pages. The accessory or subordinate flexures or uplifts pertaining to the Uinta system, that lie within this district, are of a peculiar and interesting character. The larger ones lie approximately parallel with and closely adjacent to the Axial Uplift, and constitute an integral portion of the eastern end of the mountain-range; but the outlying smaller flexures are not only separate from the first named, but also from each other. The smaller ones diminish in

scope with their distance from the main axis, and diverge or sweep around to the southeastward as they stretch away from the Uinta Mountains. Although there is a greater or less degree of divergence of these subordinate axes of flexure, they have neither a common origin nor a common radial center in either of the two mountain systems; but the position of some of them, at least, shows equally intimate relations with both. There are within this district three of these subordinate flexures or uplifts which have intimate relations with the Uinta system, and that have received distinctive names, besides two peculiar isolated mountain upthrusts, all of which will be described separately on following pages. These are the Plateau, Midland, and Raven Park Uplifts, and Junction and Yampa Mountain upthrusts, all of which are shown in their relative positions in the sections at the bottom of the geological map accompanying this report.

UPLIFTS AND UPTHRUSTS.*

The Axial Uplift.—This term is applied to the main flexure of the Uinta system. The general course of the axis of this flexure through the northern portion of this district is eastward, with a broad curve, the concavity of which is to the southward. Its course is plainly indicated on the geological map by the outcrops of the formations that border both the eastern and western portions of Axial Basin.

Upon reaching the eastern borders of this district the Axial Flexure bends quite abruptly to the southward, and is lost among the hills that lie to the eastward of Agency Park, which are a part of the foot-hills of the Park Range of mountains. A short branch of the Axial Flexure separates from the main portion at the eastern border of the district, and turns abruptly in a direction a little west of northward, passing near Cañon Park, and blends with the general uplift of strata as they rise toward the foot-hills of the Park Range, north of Yampa River.

Judging from the phenomena now presented by the eastern end of the Axial Uplift, it seems probable that at least the portion of it which lies within and adjacent to this district was at first a simple, approximately uniform, upward flexure; and that while a part of it remained as originally flexed, those portions that now form the mountains were more or less sharply uplifted from the remainder, the added displacement amounting to thousands of feet. We find that the axis of the main Uinta uplift is prolonged eastward from the eastern end of that mountain range as a comparatively slight flexure of Cretaceous strata, which blends with those of the Park Range foot-hills, as before described, and that the mountains of the Uinta system are composed of those strata only that have been thus sharply uplifted, although the latter have suffered immense erosion since their elevation. Possibly they would have suffered still greater erosion if it were not that the uplift has brought up the comparatively hard Carboniferous strata, and those of the still harder Weber quartzite, so high that they now constitute the visible portion of the whole mountain range. The amount of displacement embraced

* In using the terms "uplift" and "upthrust," I do not thereby intend to express any opinion as to the actual direction of movement in the displacement of the strata, whether upward or downward. The terms, especially the first, will be readily understood, and it seems more convenient for the reader and investigator to regard, at least tentatively, the lower, which is the larger mass, as the fixed one; and the higher, which are relatively the smaller masses, as those that have been uplifted. The term "upthrust," so far as I am aware, has not been used before. Its applicability will plainly appear in the following descriptions of the displacements of Junction and Yampa Mountains.

by this separate elevation of the Palæzoic rocks above the adjacent Cretaceous strata which now cover the less uplifted part of the Axial Flexure reached from 7,000 to 8,000 feet, and the displacement was accomplished partly by faulting this immense thickness of strata and partly by very abrupt flexure.

The eastern end of the mountain portion of the Axial Uplift terminates by a broad, sweeping, or partiversal* dip of the strata, which dip is abrupt, much like that of the sides of the uplift. That part of the terminal mountain mass of the main range which lies within and upon the northern boundary of this district consists of Carboniferous strata, and is flanked at its base by the upturned edges of the Jura-Trias, Dakota, and Colorado groups successively. The strata of the Colorado Group, however, quickly become horizontal, or nearly so, and occupy the low ground around the mountain; but they are there partly obscured by the strata of the Uinta Group. A very large part of the mass of the Uinta Mountain Range consists of the Weber quartzite, which great formation is probably about fifteen thousand feet thick. All the visible portion of the Axial Uplift, however, that lies within this district, consists of Carboniferous strata alone, except the Weber quartzite, which is exposed in Junction and Yampa Mountains, presently to be described; and is also, perhaps, very slightly exposed at the point where Signal Shot Creek Cañon opens into the eastern portion of Red Rock Basin.

Junction Mountain Upthrust.—As regards their structure and origin, Junction and Yampa Mountains are most remarkable isolated mountain masses, both having essentially the same structure, and doubtless a simultaneous origin. Both are situated upon the axis of the Axial Flexure, eastward of and separate from the main mountain masses of the Uinta chain and from each other, and where that flexure is comparatively slight.

Junction Mountain is situated three or four miles east of the terminal mountain mass of the Uinta chain, between which two mountains Snake River flows to its confluence with the Yampa. Although this mountain is so near the other mountains of the Uinta system, and is so evidently a part of that system, it is, nevertheless, entirely isolated in its structure and elevation as well as by its position. It consists of a separate and distinct upthrust of the Carboniferous and Weber quartzite strata through those of Mesozoic and Cenozoic age, which have remained almost undisturbed in the immediate neighborhood by that separate and remarkable displacement. The manner of this displacement, which I have called an upthrust, may be illustrated by the action of a large punch, worked by machinery, for perforating heavy iron plates, so clearly defined does the separation appear to be between the uplifted and the surrounding strata. The illustration will doubtless be more accurate if we imagine the punch and die to have become so worn by use that the iron plate is torn in places and nowhere clearly cut in the process of punching. This mountain upthrust is oval in form, the long diameter being nearly twelve miles and the short one about four miles. The strata about midway of both sides are nearly or quite vertical, while the dip at the northern and southern ends, although steep, is much less than at the sides.

The direction of the long diameter is northwestward and southeast-

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*All anticlinal axes must necessarily dip more or less in some portion of their extent; but in this region there are many examples of very short and rapidly-dipping anticlinals around the vanishing end of which the strata dip by a sweep of the greater or less part of a circle. I apply the term "partiversal" to such a dip, and use it in a sense similar to that in which "quaquaversal" is used for a dip in all directions.

ward, and neither this diameter nor the short one coincide with the direction of the axis of the main uplift. Its independence of the great axis, however, is not without some analogy in that of the Plateau Uplift and the Yampa Mountain Upthrust, for the main axis of the Uinta system makes a broad bend to the northward opposite Yampa Plateau, which the axis of the Plateau Uplift does not coincide with; and it is the short axis of the Yampa Mountain Upthrust, and not the long one, that coincides approximately with the general direction of the main Uinta axis. These diverse positions of the axes of the accessory uplifts and upthrusts in relation to the main axis, as well as the separateness of each of these displacements, seem to be in keeping with the assumed superaddition to the primary Axial Uplift, as has been before suggested.

The amount of the relative upward displacement of the strata that now constitute Junction Mountain is easily computed from the known thickness of the intervening groups in that region. For example, the top of the Weber quartzite, as seen in the cañon which Yampa River has cut through Junction Mountain, has been raised to a height that is about equal to that of the top of the Colorado Group, as it now exists in immediate proximity, or the plane that its top would now occupy there if it had not been removed by erosion. Therefore, the sum of the thickness of the whole of the Carboniferous, the Jura-Trias, and the Dakota and Colorado groups is equal to the entire upward displacement of the strata that now constitute Junction Mountain, because all these groups of strata intervene between the top of the Uinta sandstone and the top of the Colorado group. The amount of this displacement is, therefore, not less than 8,000 feet, as will be seen by referring to the thickness that I have assigned to those groups in Chapter III. Such an extraordinary displacement as this, and the no less extraordinarily small limit within which it has been confined, seems to justify the use of the term "upthrust," as distinguishing it from ordinary uplifts.

The illustration of the manner of this upthrust that has been used, by comparing it to the action of a dull punch upon a plate of iron, so that the sides of the hole would be somewhat torn in places instead of being everywhere cleanly cut, is appropriate, from the fact that at three or four places upon the borders of the upthrust, and near or at the base of the mountain, there are portions of Triassic strata that have been separated in the upward movement, but have been dragged up and thrown over backward, or otherwise tilted, and, as it were, caught in the jaws of the fault. The position of some of these dragged portions is shown upon the geological map.

The illustration of the action of a dull punch that has just been used, is still further applicable to the broadly-rounded surfaces of the uplifted strata, producing a gentle quaquaversal dip from the center to near the borders of the upthrust, where the dip becomes suddenly greater, or a fault. The outline of the upthrust, as before remarked, is oval, and the faulting seems to have taken place only, or mainly, at the sides. At the ends, the strata appear not to be faulted, but only strongly flexed.

Yampa Mountain Upthrust.—The general description that has been given of Junction Mountain, as to its origin and structure, will apply in almost every particular to Yampa Mountain. The amount of displacement which its strata have suffered in relation to those that immediately surround the upthrust, is a little greater than that of Junction Mountain, although the size of the Yampa Mountain Upthrust is a little smaller than the other, and its position is somewhat remote from the other mountain uplifts of the Uinta Range. This mountain upthrust lies

about sixteen miles eastward from that of Junction Mountain, with its long diameter upon and directly across the low, eastward extension of the Arial Flexure of the Uinta Range. Its long diameter has a direction a few degrees west of southward, and, therefore, it does not correspond with the axes of any of the other uplifts of the Uinta system. Upon casual view it might be expected that the long diameters of both these upthrusts would be found to correspond with the axis of the Uinta Range, or at least that they would correspond with each other, since the two mountains are so similar, and both occur on the same axial flexure. On the contrary, if lines drawn through the long diameter of each of the upthrusts were produced southward, they would meet at an angle of about 50°. The relative position of the long diameters of these upthrusts is in keeping with the curvature of the Axial Flexure upon which they are located, as it sweeps around from the Uinta to join the Park Range system; and their transverse instead of longitudinal position upon that flexure is probably due to simultaneous impingement of force that was exerted from both the adjacent mountain systems while the upthrusts were in progress as superadditions upon the original flexure.

The strata of the Colorado Group which surround Junction Mountain are much obscured by the overlying drift and the soft strata of the Uinta Group. The strata of the Colorado Group also closely surround Yampa Mountain, and are also largely obscured by the same deposits as in the other case.

The escarpments of the Fox Hills and Laramie groups that border both sides of the long Axial Basin reach within the immediate vicinity of Yampa Mountain; but the strata of the escarpment upon the southern side, while they partake of the general axial flexure, do not seem to have been especially flexed or otherwise disturbed by the extraordinary movement of this upthrust except at its immediate borders. Those on the northern side, however, are found to have been abruptly flexed to the northward by the less abrupt elevation of the strata composing the northern portion of the upthrust. The character of these two upthrusts is partially illustrated in the long section at the bottom of the geological map accompanying this report, and still further by the longitudinal section of Yampa Mountain upon the same sheet.

The Plateau Uplift.—The long, broad mountain mass which has been designated as Yampa Plateau upon the accompanying and other maps, is not strictly parallel with the axis of the adjacent portion of the main uplift of the Uinta Range, yet it is, in an important sense, a parallel and accessory flexure. It is not, properly speaking, divergent from the main axis of the range, but by its northern side it lies closely adjacent to, really parallel with, a corresponding portion of the southern side of the main uplift, with which it in part coalesces; and yet the Plateau Uplift is quite independent in its termination at both ends, as well as nearly or quite so by a separate synclinal flexure. In a mere topographical sense, Midland Uplift also constitutes a part of Yampa Plateau, but for geological purposes that uplift must be separately considered. In some degree Plateau Uplift is an epitome of the great Axial Uplift, for it also consists of the full series of Carboniferous strata together with a central mass of the Weber quartzite. Its manner of uplift is also similar, for it rises by an abrupt flexure of the strata upon either side, the flexure of the strata between being comparatively slight. This character, as well as the relations of the Plateau Uplift to its associated displacements, is shown in one of the sections at the bottom of the accompanying map. The flattening of the flexure between its two abruptly-bent sides gives the uplift its plateau-like character, which, how-

ever, is preserved in only a part of it, the remainder being narrowed by the erosion of Fox Creek Valley, and in part modified by the spur-like termination of both ends.

The width of Plateau Uplift varies from about five, to ten miles; and its extreme length as a mountain elevation is about forty-five miles. It is widest at its western end, where it terminates by two great spurs or mountain ridges, namely, Split Mountain and Section Ridge, each of which has a westward-dipping anticlinal axis, and consequently a partiversal* dip of its strata. At its eastern end, however, it terminates by only one dipping anticlinal, with its abrupt partiversal dip, the sweep of which is broader than that of the two western ones. The eastern end of the Plateau Uplift extends so far eastward as to blend with the terminal mountain mass of the axial portion of the Uinta Range. The intimate connection of the Plateau Uplift with that of the main Uinta axis will be understood by the statement that the two are separated only by a sharp synclinal axis, which is in part a fault. The maximum amount of this displacement is fully 2,000 feet; but in some places, nevertheless, the mountain masses of the two uplifts are blended together topographically just as the Midland Uplift, presently to be described, is in part blended with the Plateau Uplift. The mass of the latter uplift is, however, in large part separated topographically from that of the Axial Uplift by the deep Red Rock Basin, described on a previous page, and by the eastward prolongation of that basin in the form of a mountain valley. The two great spurs which project from the western end of Yampa Plateau, with their rapidly-dipping anticlinal axes and the regular partiversal dip of their strata, are remarkable for their magnitude as well as for their inherent peculiarities. They are really great mountain masses, their summits being more than 3,000 feet above the neighboring portion of Green River, which traverses Split Mountain by a profound cañon, as has been described on a previous page of this report.

The Midland Uplift.—The amount of displacement which took place in the elevation of this uplift is nearly 5,000 feet from the strata of the Colorado Group which flank it immediately to the southward, and which remain there comparatively undisturbed; and yet this displacement is about 3,000 feet less than that of Plateau Uplift, with which Midland Uplift lies parallel and in close contact. The influence of the latter uplift extended still farther eastward; but it is only the mountain portion that is specially discussed under this head. This portion constitutes the topographical feature I have called Midland Ridge, as well as a part of Yampa Plateau, with which it is continuous. The strata exposed to view by the Midland Uplift are almost wholly those of the Jura-Trias groups. Those strata that have been definitely referred to the Jurassic period, as well as those of the Dakota Group, flank the uplift all along its southern border; and upon the highest portion of the Ridge there is also a small area that is capped by these strata. The red beds of the Jura-Trias have been much exposed by erosion in a very large part of the Ridge, their bright colors and great elevation above the surrounding country making very conspicuous and striking features of the landscape. The mountain portion of Midland Uplift, the eastern part of which I have called Midland Ridge, does not extend so far eastward as the mountain masses of the plateau and great axial uplifts do; but as a flexure, Midland Uplift extends much farther eastward. Its axis also makes a bend to the southward in the course of its eastward extension, somewhat like that of the eastward extension of the Axial Uplift;

* See foot-note on page 42.

and, passing through the southern end of Piñon Ridge, it crosses White River and quickly disappears by a partiversal dip of the strata of the Laramie and Wasatch groups. The extent of the displacement of this eastern portion of Midland Uplift is much less than that of the western portion, and has brought to view no strata beneath those of the Cretaceous groups.

Midland Uplift consists essentially of a monoclinal flexure, with the rise upon the northern side. The flexure is quite as distinctly monoclinal in the less displaced eastern portion as it is in the western part, where the northern side of this uplift is in contact with the southern side of Plateau Uplift. The facts observed seem to warrant the conclusion that all the flexures of the strata which pertain to the Uinta system within and adjacent to this district were simultaneous in their origin, and that the movement of elevation of these folds proceeded simultaneously up to a certain stage and then halted in their common upward movement. Also that the special elevation of the mountain masses, which occupy either the whole or the principal part of each of the original folds, then took place as sharply-defined superadditions to their initial elevation, which culminated in the Uinta Mountain system. It is also evident (assuming for purposes of description the *actual* uplift of these folds) that certain of the specially-elevated accessory uplifts halted in their upward movement, while that of the adjacent larger or principal ones continued. This view is supported by the fact that all along the flexure which divides Midland Uplift from that of Yampa Plateau the strata of the former are sharply flexed up against the latter, presenting the appearance of having been dragged by the superadded upward movement of the Pateau uplift.

Midland Uplift terminates at its western end by narrowing rapidly to a point against the southern side of Section Ridge, so that the Cretaceous strata, which are flexed up against its own south side, are continued in like manner without interruption or material change in dip along the south side of Section Ridge and around its western end, as will be further explained under the head of flexures.

Raven Park Uplift.—The middle of this uplift is some eight or ten miles south of the southern border of Midland Uplift. It is thus not only isolated from all those that have been before considered, but its elevation has involved a much less amount of displacement of the strata of the region than that of any of the others, the lowest strata that have been brought to the surface upon its axis being those of the Colorado Group. In this respect it resembles the less elevated eastern portion of both the Axial and Midland Uplifts, but it is free from any superadded uplift or upthrust, such as has taken place upon those primary uplifts. By this characteristic, as well as by its local separation and slight relative elevation, it is distinct from the Uinta Mountain masses, but it is nevertheless an outlying fold belonging to that system of uplifts.

Raven Park Uplift is a very short one, not more than twenty-five or thirty miles long, its eastern and western extent being scarcely so great as that of Midland Uplift, from which Raven Park Uplift lies immediately southward. Its longer axis, however, is not parallel with that of those portions of the three uplifts that lie directly north of this uplift, but its direction is northwestward and southeastward; in this respect conforming in general direction with the southerly sweep of the eastern end of both Axial and Midland Uplifts. The significance of this change in the direction of these axes from that of the general trend of the Uinta Chain is doubtless to be sought in the fact of their approaching relation to the uplifts and flexures of the Park Range system. The flexure of the southern

side of this uplift, which I have called the Raven Ridge Flexure, is much more abrupt than that of the northern side. This is also a peculiarity of the eastern prolongation of the Midland Uplift, the southern flexure of which is a part of the Great Midland Flexure, and also of the western portion of the Danforth Hills Uplift, presently to be described. In short, it is a common peculiarity of the flexures that are embraced within the sweep of the eastward extension of the Axial Uplift, as it extends from the Unita system to join with the Park Range system; but it is not a peculiarity of the Axial Uplift itself, which has a nearly uniform curvature or flexure from side to side. The significance of the greater abruptness of the dip upon the southern side of these secondary uplifts is, no doubt, to be sought in the forces which have acted laterally as well as vertically in the elevation of the two great ranges of mountains, at least within the angle formed between the two within this district.

The dip of the strata is in all directions from the middle of Raven Park, but it varies much in degree in different directions. It is very slight to the northward and westward, not reaching so much as 10 degrees, while in the Raven Ridge Flexure, at the south side of Raven Park, the dip is as much as 60 degrees, from which point it diminishes both eastward and westward, until the uplift, as such, finally disappears.

The Danforth Hills Uplift.—Eastward from the eastern end of the Plateau and Midland uplifts, and between them and the displacements that are more properly referable to the Park Range system, there is a broad, irregular synclinal, which is occupied by the strata of the Wasatch and Green River groups, of Tertiary age. The depth and importance of this synclinal is shown in one of the sections at the bottom of the accompanying geological map. Its importance still further appears by the fact that the difference of displacement between the top of the Green River strata which rest upon it and that of the Carboniferous strata that are exposed in the uplifts and upthrusts that have been described, the latter of which are less than half a dozen miles from its borders, is more than 10,000 feet. This great synclinal is partly surrounded by an outcrop of the strata of the Fox Hills and Laramie groups, which are upturned by the Midland Flexure as it traverses by a tortuous course almost the entire length of the district. Adjoining the northern side of this broad synclinal is the Danforth Hills Uplift, which, although a comparatively slight one, derives peculiar interest from the fact that it is so intimately connected with the displacements of both the neighboring mountain systems that it cannot be exclusively referred to either. The displacement of strata involved in this uplift upon its northern, or rather northeastern, side is comparatively slight, because they connect by a very gentle synclinal with those that have been still more elevated by the Axial Uplift, and the general rise of all the strata of the district toward the foot-hills of the Park Range. The displacement at the southern side of this uplift, however, is very great, the drop of the Midland Flexure there being not only very abrupt, but it amounts to more than 3,000 feet.

The Danforth Hills Uplift is bounded on its southeastern side by the Midland Flexure, its other boundary being a gentle synclinal that extends eastward from the point of junction of the Midland Flexure with that of the Great Hogback, in Hogback Valley, and sweeps around, but within, the entire eastern end of the Danforth Hills, and thence northwestward along their northern slope, fading out in the vicinity of Yampa Mountain, where the uplift as a separate displacement also disappears.

Sundry uplifts.—Besides the uplifts that have been specially described on preceding pages, certain portions of others reach within the boun-

daries of this district. Among these is the northern extremity of the Great Elk Mountain Uplift, the principal part of which has been so ably described and illustrated by Mr. W. H. Holmes in his report for 1874. Although the principal mass of that uplift is more than a hundred miles distant to the southward, its northern vanishing end is in the bluffs that form the northern border of Agency Park, where it is separated from the southeastern end of the Danforth Hills Uplift only by the gentle synclinal that has been before mentioned as a part of the boundary of the latter uplift. The connection of Elk Mountain Uplift will be further referred to under the head of "Flexures."

Two or three very faint uplifts, or undulations of the strata, cross Green River from the southeastern part of this district. These are doubtless the result of the same force that elevated the Uinta Mountain system, as it diminished in intensity with the distance from the great axis.

Besides the uplifts the boundaries of which may be defined, there is a general uprising of all the strata, to the eastward, against the western flank of the Park Range system. It is upon this broad, gently-inclined plane of strata that a portion of the minor uplifts already described are defined. Even the eastern termination of the great Axial Uplift of the Uinta system extends upon this elevated inclined plane of strata which has been lifted as a part of the Park Range system.

FLEXURES.

An uplifting, of course, always implies the flexing of the strata uplifted; but in this district the conditions of displacement and subsequent erosion of the strata have been such as to make it desirable to give separate names and descriptions to certain flexures. For example, the principal uplifts that pertain to the Uinta system, namely, the mountain portion of the great Axial Uplift, including the two upthrusts, and the Plateau Uplift, do not, like some others, consist of a nearly uniform convex flexure, but of two more or less abrupt lateral flexures, one at each side, with a comparatively slight convexity between them. Others, and this applies to all others in this district except the eastern extension of Axial Uplift, which consists of a gentle, uniform, upward flexure, have one side very much more abruptly flexed than the other. This difference is so great in some cases as to give almost a true monoclinal character to the flexure of the whole uplift. In all cases of this kind in this district the steeper dip is on the southern, southwestern, or western side of the uplift, according to its position; or, in other words, upon the inner side of the great curve which those displacements form as they reach from one mountain system toward the other. It is these steeper flexures to which I have given distinctive names, and which are briefly described in the following paragraphs.

The Grand Hogback Flexure.—The Fox Hills strata, that flank the west side of Elk Mountain, Mr. Holmes has shown, extends northward as a continuous hogback, which he has called the Grand Hogback, a hundred miles or more, it being the same one that crosses White River and separates Agency, from Powell's park. The flexure by which that great line of hogbacks has been produced I have called the Grand Hogback Flexure. It belongs, of course, to the Park Range system; but, after crossing White River Valley, which it does in an almost due north and south line, it becomes continuous with the great Midland Flexure, which extends in a tortuous course through this district and blends with the principal Uinta displacements. The latter flexure is, then, as much an integral part of the Uinta system as the former is of the Park Range system.

Although the Great Hogback and Midland flexures are practically one and the same, their separate lines of hogbacks approach each other at an obtuse angle about eight miles north of White River, at the east side of Hogback Valley. Here the continuity of the two great flexures is unbroken, but at the point of meeting of the upturned strata of the hogback lines there branches off the shallow synclinal axis which sweeps around the southeastern end of the Danforth Hills Uplift, and thence extends along its southern side.

The Grand Hogback Flexure is nearly a true monoclinal one. The strata that lie to the eastward of it dip gently to the westward from the foot-hills of the Park Range to the flexure proper, where they have a maximum dip of nearly or quite 75 degrees, and then immediately stretch out nearly horizontally. The strata originally involved in this flexure, as they now appear at the surface, are those of the Colorado Group to the Green Group, inclusive, the maximum dip now appearing in the comparatively soft strata of the Wasatch Group. Subsequent erosion has so far removed portions of these strata that only those of the Green River and Wasatch groups now occupy the surface west of the line of maximum flexure. Those of the former group, that now remain, are nearly horizontal, and have evidently been little if any affected by that great flexure, although it is so near their present escarpments.

The Midland Flexure.—This flexure is, in some respects, the most interesting displacement of strata within the limits of this district, especially as regards its great length and unbroken continuity from one mountain system to the other. It is continuous with, and in fact a part of the Great Hogback Flexure, which, as before shown, is so intimately connected with the Elk Mountain Uplift. From the point of its nominal connection with that flexure in Hogback Valley, Midland Flexure extends in a tortuous course through the whole remaining length of the district to the flank of the principal uplift of the Uinta Range, with the lateral flexure of which it blends and becomes continuous far beyond the western boundary of this district. The course of Midland Flexure is northwestward about twenty miles up Hogback Valley; thence due west nearly ten miles; thence almost directly south nearly fifteen miles to the southern end of Piñon Ridge, around which it bends abruptly; thence in a straight direction, 15° north of west, about fifty miles. At a point about midway of the latter distance it coalesces with the flexure of the south side of Midland Uplift, with which it is in fact a part, all the way westward from the southern end of Piñon Ridge. From the flank of Midland Uplift, Midland Flexure is continuous to and along the south flank of Section Ridge, where it blends with and becomes a part of the Fox Creek Flexure; thence around the western end of Section Ridge, into the retreating angle formed by the dipping synclinal between Section Ridge and Split Mountain. From here it sweeps around the end of Split Mountain as it did around that of Section Ridge, and into a similar but much broader retreating angle or notch, at the apex of which is Island Park; thence by an abrupt bend to the westward, along the flank of the main uplift of the Uinta Range, and far beyond the limits of this district. It is thus shown that this remarkable flexure, regarding both the Great Hogback and Midland flexures as really one, can be traced continuously from the west flank of Elk Mountain Uplift to the south flank of the main Uinta Uplift, a distance of more than two hundred miles. Throughout the greater part of this distance a large proportion of the strata that are involved in this flexure are exposed in long lines of hogbacks, which constitute more or less conspicuous topographical features. The dip of the strata, in all the long reaches of this flex-

ure, is away from the axes of the two mountain-ranges, respectively, which the flexure connects; for its position there is upon the distal side of each of the uplifts which it successively flanks. In all these places the dip is very abrupt, but it is much less in all the partiversal sweeps around the end of the dipping anticlinals and in the sag of the dipping synclinals than elsewhere. The continuity of the narrow outcrop of the strata of the Dakota and Jurassic groups around the end of the mountain portion of Axial, Plateau and Midland uplifts would, at first sight, appear to indicate a separate flexure there; but this apparently continuous outcrop belongs in fact to the three different displacements just named, and portions of it are continuous respectively with the Yampa, Fox Creek, and Midland flexures. The character of the latter flexure, as well as the strata involved in it at various points, is shown in the sections at the bottom of the accompanying geological map.

The Fox Creek Flexure.—From the point where this flexure blends with Midland Flexure at the south side of Section Ridge, it passes eastward in a gently sinuous direction, forming the dividing displacement between Midland and Plateau uplifts. Then, sweeping around the eastern end of the latter uplift, it ends against the Yampa Flexure, which in turn sweeps around the eastern end of the terminal mountain-mass of the Great Axial Uplift.

Fox Creek Flexure is a very abrupt one, the maximum dip being nearly vertical, and it embraces a maximum displacement of about 3,000 feet. The strata involved in it, which appear at the surface, are those of the Jura-Trias and Carboniferous. Its general character is shown in the sections at the bottom of the accompanying geological map. A marked peculiarity of the flexure is the apparent dragging of its strata against the side of the Plateau Uplift, which has before been mentioned.

The Yampa Flexure.—From its sweep around the terminal mountain-mass of the Axial Uplift this flexure extends westward, and constitutes the dividing displacement between the Plateau and Axial uplifts. Its general direction is approximately parallel with that of the Midland Flexure, except that toward its western end it bends away to the northwestward. It ends abruptly, at least in part, against a great north and south fault at the western end of Red Rock Basin, the western wall of which fault also constitutes the end of the basin.

The flexures that have been herein described are all nearly true monoclinal flexures, at least in their more abrupt and characteristic portions. But Yampa Flexure is different in this respect, since it forms an abrupt synclinal with the almost immediate rise of the strata which form the southern side of the great Uinta Uplift. This flexure itself has a nearly true monoclinal character, similar to that of the Fox Creek Flexure at the other side of the Plateau Uplift. Contrary to the general rule, however, in the case of the secondary uplifts, Plateau Uplift has its strata sharply flexed upon both sides, instead of one only, the distal side. In this respect Plateau Uplift possesses a peculiarity that has been shown to characterize the main uplift of the Uinta Mountain system as well as some of its accessory uplifts.

Within the southern border of Red Rock Basin, and some five or six miles from its western end, Yampa flexure divides into two branches, both of which are monoclinal, the northernmost or lower one having 400 or 500 feet greater displacement than the other. The aggregate displacement of strata at the western end of the flexure is not far from 3,000 feet, which amount gradually lessens to the eastward, where also the synclinal becomes narrower and shallower. Circumstances did not permit a careful examination of the mountain-mass at the western end

of Red Rock Basin; but indications were observed that at least the upper or southern branch of the flexure just referred to passes through the mass to the northwestward.

The Raven Ridge Flexure.—This flexure forms the southern and steeper side of Raven Park Uplift. It has already been mentioned as having a dip of about 60° opposite the middle of Raven Park, which dip rapidly diminishes as the Uplift fades out both eastward and westward. Opposite Raven Park the strata of the Fox Hills, Laramie and Wasatch groups are involved, the former constituting that part of Raven Ridge and the latter passing under the nearly horizontal strata of the Green River Group, by a monoclinal flexure. Although the flexure itself diminishes very rapidly to the northwestward, Raven Ridge itself is continued much farther in that direction, where it is successively made up of the strata of the Fox Hills, Laramie, Wasatch, and Green River groups; those of the first two groups leaving the ridge successively as they spread out to the northeastward of the ridge.

CONCLUDING REMARKS.

The facts observed in, and in the neighborhood of, this district show conclusively that, although the Uinta and Park ranges of mountains have their axes at right angles, and are also separated by a considerable space of country, the two mountain systems are intimately connected by continuous and interplicated displacements. These facts, together with the further one that there are no displacements between the two systems that can in any way be regarded as breaking their connection, seem to suggest the approximately simultaneous elevation of both systems. This idea is further strengthened by the fact that a mountain axis may be traced, at least indistinctly, from the main range of the Rocky Mountains, northwestwardly through the Park Range, describing a curve, which, if produced, would point in the direction of the axis of the Uinta Range.

It has already been suggested that the various movements of displacement in the Uinta system were not uniform in their rate of progress, and only in part simultaneous. It should, therefore, not be expected that the details of elevation of the two systems were all simultaneous with each other. It is nevertheless probable that the whole Rocky Mountain system, including the Park Range, as we find it developed in Colorado, and the Uinta system, have had essentially a common physical history; although each system presents some characteristics peculiarly its own, or at least different from the other.

CHAPTER V.

SURFACE GEOLOGY.

RELATION OF THE VALLEYS TO GEOLOGICAL STRUCTURE AND DISPLACEMENTS OF STRATA.

Except in such rare instances as that of a stream having its course upon or near a synclinal axis, nothing is more evident than that, as a rule, all streams have been the instrument by which their own valleys were excavated; and, even in the doubtful cases referred to, it is probable that an examination of other portions of the same valley would show a confirmation of, rather than an exception to, the general rule. This proposition accepted, leaves other questions of a remarkable character, which are unexplainable upon any except geological grounds. For example, in the Rocky Mountain region we not only often see a river traversing an elevated district, cutting its course by a deep cañon in the underlying rock, while the land-surface is much lower not many miles distant than that which the cañon traverses, but we have examples of rivers cutting directly through a mountain uplift, and at right angles with its axis. Furthermore, cases of this kind occur in which the mountain uplift is not only a high one, composed of much harder rock than that of any of the surrounding strata, but the softness of the latter and the slight elevation of the surface they occupy seem to offer an especially favorable opportunity for the river to pursue its course around, rather than through, the mountain uplift. In fact, nothing is more apparent in the Rocky Mountain region than that the courses of the rivers are independent of the flexures which the strata have suffered over which they flow, and that their courses are also independent of the present character of the surface.

The only explanation I am able to give for this condition of things, or the one presenting the fewest objections, is, that the streams were established where the conditions of the surface then favored the course which they pursued, and before the strata were flexed to any considerable extent; that all the important displacements of strata, including the mountain uplifts, have taken place since the streams began to excavate their valleys. Therefore the movements of these displacements must necessarily have been exceedingly slow; never more rapid than was the deepening of the channels of the rivers by the ordinary erosive action of their flowing waters, or, if so, the elevation was not enough to produce a permanent damming of their waters, or a material deflection of the course of the stream. When the streams were first established, they must, of course, have found their way to the sea over the then less elevated portions of the surface; but during the ages that have since passed, the continent has continued its elevation; the strata have been variously displaced, in some cases producing great mountain flexures. Added to all this, the subaërial denudation has been so great that doubtless no trace of the surface upon which the rivers were originally formed now remains. Indeed, it is known that, although the channels of at least some of the rivers of the Rocky Mountain region occupy a somewhat greater actual height above the level of the sea

than they did when they were first established, they have cut their way through many thousand feet in thickness of strata which were originally beneath their beds, and which have been brought up from below against the wearing action of the constantly-flowing stream.

Not only have the valleys been thus carved out by the flow of the perennial streams, but their minor or tributary drainage-channels; mostly those having only a periodical flow of water, have carried away from the surface such an immense bulk of material, that great mountain masses now remain in many places that are only shreds of the formations that were once spread continuously over the region. This tributary drainage has produced what are now the most conspicuous topographical features of the great Rocky Mountain region, in the course of which the channels have been much influenced in their direction and position by the varying conditions of the strata with which they have been brought in contact. Therefore the drainage of this latter kind has been called consequent drainage, while that of the permanent streams has been designated as antecedent drainage. The larger streams have of course had their tributaries from the beginning, but it is hardly likely that the identity of any, except those which contain perennial water, have been fully preserved; while not only the identity, but the exact position of nearly or quite all the streams that contain perennial water have remained unchanged from the beginning. This district, together with that which adjoins it on the north, affords some remarkable examples of antecedent drainage in connection with great and abrupt displacements of the strata that are crossed by the drainage-channels.

Green River.—The cutting of Green River through the Uinta Mountain chain is probably one of the most extraordinary examples of this kind to be found on the continent, but as this has been fully described by Professor Powell in his report on the geology of the Uinta Mountains, and as only a small proportion of the wonderful cañons of that river exist within the limits of this district, a full description of even those of the Uinta Mountains will be omitted in this report. The portion which lies within the limits of this district is most impressive and remarkable, cutting, as it does, through Split Mountain from its base to its summit. This mountain is a sharply-folded spur, which projects westward from the body of Yampa Plateau, the summit of which is 3,000 feet above the river; and is composed, like the principal part of the plateau, of hard limestones and sandstones of Carboniferous age. The strata surrounding Split Mountain to the westward are comparatively soft, and the surface there has comparatively slight elevation. Viewing the region topographically, the most natural course for the river to have pursued from and below Island Park would seem to be by way of a tributary drainage, and the main channel of Brush Creek, around the western end of the mountain, instead of cutting entirely through it, as it does, splitting it through its highest portion. Below Split Mountain the relation of the river to the underlying strata is not especially remarkable.

Yampa River.—Although the cañons of the Yampa are not so deep as many of those of the Green and Colorado Rivers are, its valley is remarkable for the extraordinary displacements of strata through which they have been excavated. From the eastern boundary of the district, nearly to Yampa Mountain, the river runs in a monoclinal valley; that is, the general course of the river is to the westward, and the general dip of the strata out of which the valley has been excavated is to the northward. Moreover, the bendings of the river coincide in some degree

with the flexed borders of the outcrop of the different groups of strata in the neighborhood of the river. Concerning this portion of the valley, upward of forty miles in length, there is nothing especially remarkable in the relation of the river to the displacements of the strata over which it flows; but in the lower portion of its valley the case is very different.

The isolated position of Yampa Mountain in the comparatively low land of Axial Basin, and its character as a sharply-defined upthrust of Palæozic rocks through those of Mesozoic age, has been already explained. Yampa River, after entering Axial Basin, which it does four or five miles eastward from Yampa Mountain, instead of bending around the mountain in the lower ground at its base, cuts, by a narrow cañon, through the northern portion of the mountain. The walls of this cañon are not only several hundred feet higher than the low ground at the base of the mountain, but the strata through which it has been cut are composed of hard limestone, while those underlying the low ground are of soft sandstones and clayey shales.

Below Yampa Mountain, the river runs for a distance of fifteen or sixteen miles, to Junction Mountain, along the low grounds of the western portion of Axial Basin, and approximately upon the main axis of the Uinta Mountain Uplift. Reaching Junction Mountain, which is another isolated mountain upthrust almost identical in character and surroundings with Yampa Mountain, the river cuts through it in the same manner as through the latter mountain, but by a deeper and longer cañon. The length of this cañon through Junction Mountain is about three-quarters of a mile in a straight line, from which its course varies a little, and its greatest depth is about 1,200 feet, the walls being almost perpendicular. As in the case of Yampa Mountain, the strata of the low grounds that surround Junction Mountain are soft and easily eroded; while the cañon is cut through not only the hard limestone and other strata of Carboniferous age, but also through several hundred feet in thickness of the still harder Weber quartzite beneath them.

After leaving Junction Mountain, Yampa River flows across Lily's Park directly to the eastern end of the high range of paleozoic rocks that have been brought up by the Uinta Mountain Uplift. It then flows more than 30 miles through a tortuous and continuous cañon which it has cut in the carboniferous strata which form that portion of the southern side of the main fold of the great Uinta Uplift, and empties into Green River where itself is passing through a deep cañon in the Uinta Mountains. The walls of the Yampa Cañon are almost everywhere nearly perpendicular, varying in height above the stream from 1,000 to 1,500 feet. Along a great part of its course Yampa Cañon lies approximately parallel with a valley that lies in the synclinal flexure between the main fold of the Uinta Uplift and the accessory one of the Yampa plateau. Red Rock Basin constitutes the western end of this synclinal valley, the bottom of which is 1,600 or 1,800 feet lower than the brink of that portion of the cañon which lies opposite to it.

Viewing this region, according to its present topography and the susceptibility to erosion of the rocks that occupy the surface, the most natural course for Yampa River to have pursued to form a junction with the Green would seem to be around the north side of Yampa Mountain, thence past the southern end of Junction Mountain through Midland Basin, and thence down the dry valley that lies along the southern side of Midland and Section Ridges to the valley of Green River. On the contrary Yampa River traverses the most mountainous and difficult portion of the district after having cut through, instead of around, two isolated mountains composed of hard and compact strata.

White River.—In no part of that portion of its course which lies adjacent to this district, does White River Valley afford so striking an example of antecedent drainage as the valley of the Yampa does. Nevertheless, the course of White River is sufficiently independent of the displacements of the strata over which it flows to show that it should be properly placed in the same category in this respect, with the Yampa and Green Rivers.

Upon leaving Agency Park, White River cuts through Grand Hogback, which crosses the valley at right angles; and from there westward to the southern end of Piñon Ridge, a distance of between 25 and 30 miles, it runs in large part upon the yielding strata of the Wasatch Group, and in part upon the lower strata of the Green River Group. It then runs for a few miles among the strata of the Fox Hills and Laramie groups, where they are upturned by the Midland Flexure. It then returns to the Wasatch Group again, upon which it runs nearly to Raven Park, where it crosses in both the descending and ascending order, the Laramie, Fox Hills, and Colorado groups. After passing the Raven Ridge Flexure at the western side of Raven Park, the river again flows five or six miles upon the strata of the Wasatch Group, and then enters a cañon which it has carved out of the strata of the Green River Group, nearly all the way to its confluence with Green River. This cañon is from 600 to 1,000 feet deep, from the adjacent upland surface; and although it is narrow, its sides are not usually so precipitous as those of Yampa Cañon are.

Throughout a large part of the course of White River, there is apparently no special condition of the underlying strata that might be supposed to have governed its direction so far as lateral deflection is concerned; but its direction seems to have been just as little influenced by the abrupt flexures the strata have suffered over which it flows near Piñon Ridge and at Raven Park.

Milk Creek.—The upper branches of Milk Creek flow in such a manner and have such relations to the underlying strata as any kind of drainage, either antecedent or consequent, might have. But from the point at the north side of Axial Basin, where these branches coalesce, the creek, instead of continuing down the low land of the open basin, as one might expect it to have done, turns abruptly northward through a cañon, or very narrow valley, three miles long and 800 feet maximum depth, which it has carved out of the strata of the Fox Hills Group, and joins the Yampa which there runs in a similar cañon.

No other theory than that of antecedent drainage seems at all adequate to explain the extraordinary course of such a creek. It is, however, most remarkable that a creek so small as this could have such a history—a history that dates back to a time before the great mountains near by were made, and before the grand lineaments which the continent now bears were carved.

SCATTERED DRIFT.

No considerable portion of the surface of the region adjoining the Rocky and Uinta Mountains is free from well-worn scattered drift-pebbles. These pebbles are composed of various kinds of rock, but they are largely quartzites of various colors, and are usually as smoothly rounded as any that are now washed upon a storm-beaten sea-shore.

To one who is familiar with the great northern glacial drift, these pebbles suggest the same or a similar history; and when we attempt to trace their origin by comparing their lithological composition with that

of the rocks *in situ* in that region, it is evident that the original ledges from which they have been separated are those of the axes of the neighboring mountains. Therefore it is equally evident that they have been distributed in radiating lines from those axes; especially so since in every case yet observed, the differences in the lithological composition of the drift-pebbles at different localities adjacent to the mountain range exactly correspond to the changes of lithological characters of the rocks comprising different portions of the mountain axis. That these drift-pebbles were distributed by glacial action seems, in view of the accepted theories in relation to the great northern drift, to be a natural inference upon casual examination; especially as this mountain drift is distributed upon the surfaces of the higher foot-hills of the mountain ranges, as well as in the valleys between them, and upon the lower lands at a greater distance. The true origin and distribution of this drift, however, involves the consideration of several questions, for the discussion of which the phenomena observable within the limits of this district do not furnish sufficient material. Therefore the consideration of the subject in this report will be mainly confined to the description, and an account of the distribution of the drift within this district. Before doing this, however, it is proper to refer briefly to some correlated phenomena. The drift-pebbles, as before mentioned, are as smoothly rounded as any that are now washed upon the sea-coast; and it seems difficult to understand how this could have been done under any condition of transportation alone. Indeed, it seems impossible that these pebbles could have been so completely rounded in any manner except by attrition in a large body of water where the waves could have great power; and this view is strengthened by the fact that the pebbles are distributed over so broad an area. Whatever their origin as such may have been, it is certain that the pebbles have been radiately dispersed from the mountain axes.

The character of the rocks composing the axial portions of the Uinta and Park Range uplifts respectively, is so different that it is quite easy to refer any collection of pebbles that may be found in the vicinity of both ranges to the one from which they were really derived, and also to recognize any mixture of pebbles as such that have been derived from both ranges. For example, it is easy to recognize the drift-pebbles of the eastern portion of this district as having been derived from rocks of those mountains of the Park Range which lie to the eastward; and just as easy to recognize those that are found in the western part of the district as having been derived from the strata of Uinta Mountain uplifts. Upon the middle portion of the district, however, the drift of both eastern and western origin; or, in other words, that of the Park Range, and of the eastern end of the Uinta Mountains, is found to be mixed. The former is mostly quartzites, with admixtures of basalt and granite, while the latter are mostly made up of fragments of carboniferous limestone and Weber quartzite, which latter rock is often, but not always, quartzitic. This Uinta drift contains no trap and no granite, for none of those rocks occur in the eastern portion of the Unita Mountains. Granite, however, is abundant in the Park Range, and very extensive masses of the basalt exist just beyond the eastern borders of the district. The pebbles of eastern drift which have found their way in abundance into the beds of the White and Yampa rivers, have been carried down by the current to points further westward in the valleys than any they have reached upon the uplands, and further than any points to which drift from the Uinta Mountains has been transported eastward.

It is upon the upland borders of Axial Basin, between Yampa and Junction Mountains, from 400 to 800 feet above the level of Yampa River, and so high that it could never have been reached by its waters, that we find the mixture of eastern and western drift-pebbles. No western drift-pebbles have been found east of Yampa Mountain, and no pebbles of eastern origin have been found west of Junction Mountain, except that which the currents of the rivers have transported as before mentioned.

Junction and Yampa Mountains seem to have stood respectively as barriers, or, at least, as obstacles in the way of the transportation of the drift-pebbles in the direction of radiating lines from the two mountain ranges. For example, in that portion of the valley of the Yampa which lies north of an east and west line through the north base of Yampa Mountain, I found eastern drift-pebbles plentiful, with only a very slight admixture of those of western origin, and even this small proportion is not certainly known to be of more western origin than Yampa Mountain, because it may have been derived from that mountain itself, which has the same lithological composition that the eastern portion of the Uinta Range has.

Furthermore, I found *very* few eastern drift-pebbles upon the surface immediately west of Yampa Mountain, and also very little western drift upon the surface immediately east of Junction Mountain. Western drift-pebbles, however, exist in great abundance upon all the surface east of the Uinta Uplift and south of an east and west line through the south base of Junction Mountain, and also extending nearly as far eastward as Yampa Mountain.

All these facts are at least suggestive of the glacial distribution of this drift from both mountain-ranges, but it is proper to say that no glacial striæ, either upon the pebbles or upon the rocks *in situ*, were observed in this district, although it is not certain that they do not exist there. Also, that the character of the underlying rocks of all that region is seldom such as to have preserved the striæ if they had ever been made upon them. As to the origin of the pebbles, as such, of which the drift is so largely composed, the phenomena observable in this district afford no satisfactory information; but their origin as pebbles was probably anterior to, and the result of, other causes than that which produced their distribution.

As to the time when this distribution took place, some important data were obtained. The unconformity of the Uinta group upon all the other Tertiary groups, as well as upon those of older date, has been mentioned, which shows that group to be of much later Tertiary age than the Bridger Group. The great outflow of basaltic trap that has been before mentioned, is known to have taken place long after the deposition of the Uinta Group, because the trap is found resting upon a considerably eroded surface of that group at Fortification Butte, five or six miles north of the northeast corner of this district.

A large percentage of the pebbles of the eastern drift of this district consists of fragments of this trap, which fact proves both the origin of the pebbles and the distribution of the drift to have been subsequent to the trap outflow. Nevertheless, this drift is known to be of great age, because there is much evidence that extensive erosion has taken place since its distribution; but still there is evidence that the great general features of the region as they now exist were produced by erosion before the distribution of the drift. So far as my observation has extended, there appears to be no reason why we may not regard the distribution of this drift of the Park range and Uinta Mountains as contemporaneous with that of the great northern glacial drift.

CHAPTER VI.

MATERIAL RESOURCES.

With the exception of coal, no mineral substances of practical value were discovered in this district, and it is not thought probable that any others of importance exist within its limits.* The material resources of the district, therefore, both present and prospective, are confined to vegetable productions alone, if we except coal, stone, and clays. One of the series of maps composing the atlas of Colorado that has been prepared by the United States Geological Survey is colored in such a manner as to show by area the natural productions and capabilities of the State. By this map it will be seen that a very large part of the surface is classed as grass-lands, and that only a small fraction of the whole surface is designated as tillable. Bearing in mind also that a large part of the surface which is there classed as aspen-lands, as well as some portions of the cedar and piñon lands, also affords good grazing, it will appear that pastoral interests are destined to exceed all others in the region of which this district forms a part, while in other districts mining interests will doubtless overshadow all others.

Tillable Lands.—As this district is far within the limits of that portion of the national domain upon which the annual rain-fall is insufficient for the purposes of agriculture, the only tillable land within the district is that which it is practicable to irrigate. Such lands are of course found only along the valleys the streams of which produce a considerable flow of perennial water. No attempt was made to ascertain the precise area of irrigable lands in this district, but the map before referred to will show it to be comparatively small. Small as it is, it is quite sufficient for the needs of a considerable pastoral population along the valleys of White and Yampa Rivers; and the grass-lands of this district are not too distant from the irrigable lands to be available for pastoral purposes from the homes that may be located in the valleys. The parks that have been described in Chapter II contain the largest bodies of irrigable land within the district, but at many other points along the valleys of all the perennial streams farms of more or less importance may be made.

The amount of irrigable land in any valley of course depends not only upon its being within reach of water from the adjacent stream by its fall, but it also depends upon the amount of water the stream carries during the part of the year that the crops need irrigating. The valley of a stream may therefore contain more tillable land within reach of its waters than those waters are sufficient to irrigate properly, but this is seldom the case with the larger streams. There is probably no portion of either White or Yampa River valleys within the limits of this district that is accessible to the river water which it is in any case insufficient to irrigate if judiciously applied. Under the head of "Water," in a following paragraph, the gauging of those two streams may be found.

The elevation of this district above the level of the sea limits the va-

* This statement may be regarded as a reply to the oft-repeated question, "Is gold or other precious metals likely to be discovered in that region?"

riety of farm-products that may be grown there successfully, but trials already made there show that wheat, barley, oats, rye, pease, beans, potatoes, and many of the common garden vegetables may be cultivated successfully. The tillable lands along the valley of Green River have less elevation above the level of the sea than those of any other portion of the district, and it is probable that maize, as well as some kinds of fruit trees, might be grown there with success. The soil of the irrigable lands is almost without exception very fertile, and needs only proper irrigation and cultivation to make them very productive.

Water.—A dweller in a well-watered country is hardly able to realize the paramount value of the water that falls upon the land in copious and timely showers, and that traverses every valley in the form of rivulets and streams. It is the want of the copious supplies of water that bless the eastern part of the national domain that renders so large a proportion of the western part either a desert waste or untillable land. For this reason water is classed among the material resources of the district, and all its permanent streams and rivulets are especially noticed in this report, although some of them are so small that they would be deemed unworthy of notice in more favored regions.

Except among the Danforth Hills and other hills in the eastern part of the district, and also at the bases of Plateau and Midland Uplifts in the western part, no springs are found, and they are not numerous in the parts designated. Therefore supplies of water must be obtained principally from the Green, Yampa, and White Rivers, and their very few tributaries that contain perennial water, and which have already been described in Chapter II. The water of these streams is sufficiently pure and good, and the fall is almost everywhere so great in the Yampa and White Rivers that abundant water-power may be obtained, as well as an abundance of water for irrigating purposes.

As a general indication of the amount of water carried by White and Yampa Rivers, I here insert a record of the gauging of each. Yampa River was gauged at a point four miles east of Yampa Mountain, and White River six miles below White River Indian Agency. The method adopted was to measure a line of 200 feet along the bank of the river, and note the time taken by a float to run from the upper to the lower end of the line; then to measure the depth at certain points opposite, together with the width of the stream.

Gauging of Yampa River, August 5, 1877.

Width from brink to brink	175 feet.
Runnin gtime of float	1 minute 57 seconds.
Depth at north, quarter of the distance across	2 feet.
Depth at center	2 feet 5 inches.
Depth at south, quarter of the distance across	2 feet 9 inches.

The bottom has, at the place of measurement, quite a uniform curve from brink to brink, so that a greater number of measurements of depth were deemed unnecessary.

Gauging of White River, August 11, 1877.

Width from brink to brink	120 feet.
Running time of float	31 seconds.
Depth at south, one-eighth distance across	1 foot 9 inches.
Depth at south, one-quarter distance across	1 foot
Depth at center	1 foot 9 inches.
Depth at north, one-quarter distance across	1 foot 10 inches.

The time of gauging of these streams was toward the close of the season when irrigation of crops is necessary. Earlier in the season, when more water is needed for that purpose, the streams always carry a greater quantity.

If future interests should ever make it desirable to have artesian wells in that region, they may, no doubt, be successfully made in several places; as, for example, in Coyote Basin, the valley between Midland Ridge and the Raven Park Uplift, in the valley of Red Bluff Wash, &c. The conditions of the strata of the district upon which this opinion is based are shown in the sections at the bottom of the geological map accompanying this report.

Grazing lands.—Although irrigation is necessary for all cultivated crops in that region of which this district forms a part, very nutritious grasses grow naturally both in the valleys and upon the uplands, those of the latter being more nutritious than those of the former. The grass upon the uplands is thinly scattered, but the extent of surface upon which it grows is so great that it will furnish an abundance of food for all the grazing animals that may be required by the limited population which the irrigable lands of the valleys are capable of supporting.

Fuel and building material.—Although there are no forests, properly speaking, in this district, there is, upon the hills and mountains, a scattered and generally stunted growth of cedar, piñon, and aspen trees, which is quite sufficient in amount to meet all requirements for fuel, fences, and such small, rude buildings as may be required for farm purposes. Easily dressed sandstone is almost everywhere abundant, from which substantial buildings may be constructed.

Besides the wood fuel, which will doubtless be quite sufficient for all the ordinary wants of the greatest population which the district will ever support, there are several localities where coal may be obtained in comparative abundance. Among the best exposures of coal that were observed during the progress of the survey are those of two principal beds, one of which is found in and near Cañon Park, and another in the Danforth Hills, northwestward from White River Indian agency. Both of these beds occur among the strata of the Laramie Group, one being near the base and the other near the top of the series. Comparatively little search will doubtless fully reveal these and other beds of coal in those places, from which supplies may be obtained with comparatively little labor. The bed that occurs in the Danforth Hills is also seen exposed in the valley sides of Yampa River below Cañon Park. This bed doubtless represents one of those at the well-known mines at Rock Springs Station, on the Union Pacific Railroad, Wyoming. The bed that occurs in the upper strata of the Laramie Group, and which is exposed in Cañon Park, doubtless represents one of those beds which were formerly worked at Point of Rocks and Black Buttes stations, on the railroad just named.

A bed of coal in the lower strata of the Colorado Group, near the south side of Lily's Park, has already been mentioned on a previous page, but it seems somewhat doubtful whether it will prove to be a good one. Although the Laramie Group contains so much coal in the eastern part of the district, there seems to be comparatively little among the strata of that group in the western part. In the region of which this district forms a part, the Fox Hills Group is known to contain some coal, but within the limits of this district no good bed of coal was discovered among the strata of that group.

REPORT OF F. M. ENDLICH, S. N. D., GEOLOGIST OF THE WHITE RIVER DIVISION.

LETTER OF TRANSMITTAL.

WASHINGTON, D. C., *April* 9, 1877.

SIR: I have the honor herewith to submit my report for 1876 as geologist of the White River division. In accordance with instructions received, we left Cheyenne, Wyo., August 14, 1876, and started for the field August 16 from Rawlins, Wyo. After a march of one hundred and eighty-five miles, we arrived at the White River Indian agency, where we commenced operations. October 12 we returned to that place, having completed the geological and topographical survey of the area assigned to us. During that time we obtained sufficient data for the purposes of preparing geological and topographical maps of a section of country comprising over 3,800 square miles.

The subjoined report is divided into three chapters and a conclusion. Of these the first treats of the physical character of the country examined, the second of its structural and geognostic features, and the third contains a short discussion upon the intimate connection between lithological constitution of rocks, stratigraphy, and special orographic features. In the "conclusion," the various geological formations I encountered in Colorado are briefly reviewed. A comparative table of formations throughout the State has been added.

I wish leave to express my sincere thanks to Mr. G. B. Chittenden, topographer directing, and to Mr. E. N. Dickerson, jr., meteorological observer, for their uniform kindness and co-operation during the field-season. To Mr. W. H. Holmes I am indebted for the preparation of illustrations.

It gives me pleasure here to acknowledge the courtesy and material aid extended to us by Mr. Danforth, agent at the White River Indian agency, and Mrs. Danforth. To them we owe, in a great measure, the friendly footing upon which we were at once placed with the Utes, besides many favors that are most heartily appreciated by those accustomed to camp life and camp fare.

Hoping that this report may meet your requirements,

I am, sir, very respectfully, your obedient servant,

FREDERIC M. ENDLICH.

Dr. F. V. HAYDEN,
Geologist-in-charge U. S. Geological and Geographical Survey of the Territories.

REPORT ON THE GEOLOGY OF THE WHITE RIVER DISTRICT.

INTRODUCTION.

During 1876 the geological survey of Colorado was completed by the four field-parties sent out for that purpose. A short season only could be devoted to the work, but it proved to be of sufficient length to finish all that had been assigned to each individual party.

On August 16 the division to which I was attached as geologist left Rawlins for the White River Indian agency, in order to survey a strip of country west and southwest from that point. To us had been assigned the region lying west of the agency, bordered on the north by the White River, on the west by longitude 109° 30′ west, on the south by north Latitude 40°, and joining on the east with the district of the late Mr. Marvine (1873) along a line of about longitude 107° 45′ west. The area enclosed within these limits comprises about 3,800 square miles. In order to expedite the work as much as possible, it was decided to establish White River agency as a supply-post for provisions, and complete the survey in two trips from that point. This plan was carried out, and proved to save time in travelling.

August 27 we left the agency, starting southward, and, after finishing the area we had expected to, we returned by a different route to our starting point September 9. Leaving it again September 11, we surveyed the remaining portion of the district. Our last station was made October 11. On the day following we left the Indian agency and marched eastward by way of Middle Park, crossing the continental divide over Boulder Pass. Snow and cold weather impeded rapid progress somewhat, but on October 22 we reached Boulder City, from where we proceeded to Washington.

In treating of the district completed during that time I have concluded to divide the discussion into two parts. The first treats of the physical character of the region, the second of the structural. Uniform in every respect, that section of country furnishes but very little of interest either to the geologist or palæontologist. It is not a pleasant region to travel through, owing to its arid character, and to the fact that much of the water which may be found, is little less than a saturated solution of carbonates and sulphates of the various alkalies. For sanitary purposes it would answer admirably well, but this peculiar feature is not particularly acceptable to any one who may be dependent upon the water he meets with for his beverage and his cooking. In the subjoined pages special mention will be made of the most alkaline creeks and springs, and the origin of the alkalies in solution will be discussed.

CHAPTER I.

DRAINAGE.

A.—WHITE RIVER DRAINAGE.

Four large streams flow into the White, heading on the Roan Mountains or Book Cliffs, and following a course of about south to north. Of these the first one (going from east to west) enters the White about 30 miles below the agency buildings. It is called Pi-ce-ance by the Indians, and we have retained the name. This stream has a length of 45 miles, and carries water during the entire year. Most of its tributaries are dry, except early in spring and during a portion of the rainy season. Douglas's Creek, named after the head-chief of the White-River Utes, is the next stream of good size; it flows into White River, about 60 miles below the agency, having a general course west of north. Shorter than this is Evacuation Creek, which joins the White 25 miles below Douglas's. The courses of the two last named are very nearly parallel. Starting with two main forks, which join at Station 32, is Two Water Creek; while its east fork, Bitterwater Fork, contains very unpalatable alkali water; the west one, Sweetwater Fork, is fresh. Below the junction we found no water whatever. Both of the last-named streams enter the White beyond the western border of Colorado, in Utah, 100 miles below the agency.

Besides these more important streams, there are several smaller ones worthy of mention. Between the agency and Pi-ce-ance is Cattle Creek, 4 miles below the former. It heads near Station 2, and after but a short run joins the White. Another creek is found between Pt-ce-ance and Douglas's, draining the low bluff country between the mouths of the two larger streams. Asphalt Wash is a dry creek east of Two Water; it is but short, cutting deeply, however, into the sandstones and shales of the region.

Near the heads of all these streams we found more or less abundant springs; many of them were flowing but feebly, during the time of our explorations (the dry season), and a short distance only. In the morning, not unfrequently, the water was more plentiful, and camp could be made at a point from which any flowing water would be removed for some distance by evening. Evaporation during the day decreased the emitted quantity, which received a fresh supply during the night, by the cessation of this evaporation, and by the precipitation of moisture as a copious dew. As has been observed in many arid regions throughout the world, so here, too, certain strata of rocks were more abundantly supplied with moisture than others. It was in such strata, or immediately below them, that springs had to be looked for. At almost every locality where the lithological character of strata shows only sandstone and shale, we will find the same occurrence. Requisite, of course, are conditions favorable to the emission of water retained by such "water-strata."

B.—GRAND RIVER DRAINAGE.

A small portion only of the drainage belonging to this river falls within the limits of our district, south of the agency. The divide between

White and Grand is but 12 miles distant, and there several creeks in our district reach the Grand without leaving it. Among them Rifle Creek is the most prominent. This heads near station 4, and flows in a general southwestern course until it enters the Grand. Roan, Salt, and Bitter Creeks merely reach our district with their head-water drainage, and, following a course east of south, join the Grand at varying intervals of space. These southern streams carry more water, *i. e.*, water for a greater distance in miles, than the northward-flowing tributaries of the White. While treating of the stratigraphy of the entire region this will be discussed.

Summarizing the approximate lengths of water-courses contained in our district, and heading within its limits, we arrive at a result which shows that the length of the main streams is a comparatively large one, as compared with the area. Did all the streams contain water throughout the entire distances of their courses the region would be amply supplied with moisture. As it is, however, it is dry.

WHITE RIVER DRAINAGE.

	Miles.
Length of White River within district	120
Cattle Creek	15
Pi-ce-ance Creek	45
Douglas's Creek	35
Evacuation Creek	30
Asphalt Wash	18
Total	263
Bitterwater Fork	22
Two Water Creek	18
Sweetwater Fork	19
Dickerson's Creek	32
Total	354

GRAND RIVER DRAINAGE.

Nameless Creek	22
Rifle Creek	17
Roan Creek	32
Salt Creek	27
Bitterwater Creek	30
Desert Creek	32
Total	160

Along nearly all of these main tributaries of the two rivers we found Indian trails, greatly facilitating travel, and frequently leading to springs which could scarcely have been found without their guidance. It is improbable that much travel should ever occur in that region, but for casual travellers the trails will prove to be of invaluable service.

TOPOGRAPHY.

The larger portion of the district is, viewed as a whole, simply an extensive plateau, which slopes to the north. Topographically it is a continuation of the Grand Mesa south of the Grand River. As generally is the case, so here, too, the geological formations prove to exhibit certain types of orographic features. We find in the eastern portion of the district that the mesozoic group is represented, and that there the country is more irregularly broken than farther west. A long line of heavy hogbacks stretches in a general direction a little east of south from the White to the Grand. At several places streams cut through this hogback, flowing westward. On its eastern face it is steep, generally

almost inaccessible, but the western slope is more gentle. This hogback ridge 52 miles in length, is about 1,400 feet above the valley east of it, presenting, as it does, good points for topographical and geological stations. East of the valley the hills rise to considerable elevation, for that section of country, so that Stations 3 and 6 are located at altitudes, respectively, of 9,904 feet and 8,533 feet. Cattle Creek flows northward through an almost straight, grassy valley into the White; a type of valley that is generally formed, of greater or less extent, wherever Colorado shales are overlying Dakota sandstones. A low divide connects this with Rifle Valley. Travelling down this latter we reach the Grand. At that locality this river flows in a broad valley, hugging the rising region on the south side. Low bluffs of variegated marls are found north of it, forming a transition between the steep hogback ridge and the valley proper. Looking off westward we see the nearly straight line of the Book Cliff. Rising to a relative elevation of 3,000 feet they present a bold escarpment to the south, one that is broken by passes at a few places only. The regular stratification and the admirable carving of the precipitous southern slope give this plateau-edge a characteristic appearance. At many places the strata composing it have yielded to eroding agents, and great masses have fallen down, producing vertical walls. Their light color and well-defined stratification make them appear as successive shelves; hence the name which has long since been given to this elevated plateau.

Immediately west of the hogback the geological formation of the plateau and the latter itself commence. Ascending a gradual slope to its summit, the divide between White and Grand, we obtain a view of the entire structure. Forming a crest which trends about east to west, the Book Cliffs retain a very constant absolute elevation of their highest points, which, however, vary but slightly from the general altitude of the ridge. On average, this may be stated as being 8,700 feet above sea-level. An Indian trail runs along the entire length of the crest, as this is by far the most convenient place for travelling. A number of springs are found on either side of the divide, not far from its summit. Riding down any of the northward-flowing streams, we observe that their headwaters are generally contained in steep, narrow gulches, which cut down deeply into the tertiary strata. Upon reaching a lower level, however, the valleys widen, are very flat, and not unfrequently show evidence of having at one time contained lakes of considerable extent. These latter have disappeared in consequence of an enormous deposition of diluvial and alluvial drift. Inflowing waters have carried with them large quantities of sand and silt. Into the lakes where the rapid progress of the stream was checked, this "removed" material has been deposited; thereby the level of the lake-beds has gradually been raised and the water flowed off. We now have, instead of bodies of water, an equivalent of alluvial and in part diluvial soil. Through this the present streams and creeks cut deep, narrow gorges. Frequently it is necessary to travel for some distance before a point can be found where these gorges may be crossed by animals. During the rainy season and early in the spring, water coming from the more elevated portions of the pleateau transports large masses of the comparatively light material, and renders the streams and White River very muddy. On either side the flat valleys are inclosed by more or less steep bluffs, showing, generally, the exposed strata on their faces. Between the streams the space is occupied by long, narrow, mesa-like ridges. East and west these show steep slopes, are connected on the south with the crest of the Book Cliffs, and northward slope very gently toward the

White. On average, this slope may be said to be less than 200 feet to the mile. Short grass covers many of the ridges along their flat tops, while the sides are grown over in part by juniper and piñon. This general character holds good as far west as Evacuation Creek. Near the junction of that with the White it changes, however. A heavy series of superincumbent sandstones has produced a change here. Marching down the creek, we remain for a long distance in an unbroken cañon, the walls of which are about 600 to 800 feet high. Four miles above its entrance into the river the trail leaves the creek, and, ascending to the summit of the long ridge west of it, strikes across toward a sharp southerly bend of the White. From there downward the river flows in a narrow cañon. Walls, averaging 1,000 feet in height, enclose it on either side, presenting almost vertical faces. A dark-brown to yellow-brown sandstone, regularly bedded, composes them. Erosion has here produced numerous fantastic figures that a lively imagination can endow with life, and readily compare with animate beings. On the isolated hills and knolls south of the cañon, which former owe their existence to remnants of this sandstone, "monuments" of all kinds can be found. Cleavage-planes in the sandstone strata have produced innumerable picturesque forms, and erosion, both by water and sand, has been the artist who shaped the original block.

For about thirty miles this cañon continues. The bed of the river is narrow, covered with shrubs and brush, which greatly impede the progress of man and animal. Dry washes coming from the north are cut deeply into the yielding sedimentary beds. Throughout the district, west of the Great Hogback, the topographical features of the region are remarkably uniform. "Like cause produces like effect" finds another application here. We find but very subordinate changes in the lithological constitution of the sedimentary beds, and in accordance therewith we notice that the general features observed undergo but slight changes.

As a rule, it may be stated that the shales and marls, whenever sufficiently compact, have produced steep, inaccessible cliffs, while the sandstones and sandy shales form more gentle slopes. Sandstones, mostly, can be found as the capping of low bluffs, which they have protected from erosive influences, thus giving rise to their formation.

Many detail features, due partly to erosion, partly to vertical cleavage of the strata, were noticed, and will be referred to at the proper place. Inasmuch as certain geological formations comprise similar or identical strata (lithologically speaking) within circumscribed areas, occurrences of such a nature may, locally, be regarded as characteristic of well-defined geological groups. Viewing the subject from this standpoint, the "monuments" and other minor orographic features become of importance to the geologist exploring.

In the subsequent pages space will be devoted to a short discussion of the influence that stratigraphy and the lithological character of strata have upon the orography in general, and upon that observed in Colorado in particular. To the field-geologist, who is required to accomplish his work with as much accuracy as possible in a very short time, hints furnished by exterior physical appearance are of the greatest value. Colorado, perhaps more than many other regions, furnishes excellent material for a consideration of this subject, and at the end of the report on that State a brief treatise thereupon may justly find its place.

VEGETATION.

Each special region of the country has its own more or less characteristic shrubs and trees. In the low valleys and along the plateau-like

ridges we find sage brush (*Artemisia Ludoviciana*) covering the ground. Greasewood (*Sarcobatus vermiculatus*), growing most luxuriantly in the dry valleys, is interspersed throughout. In the moist valleys willows (*Salix nigra*) occur in dense masses ,often very effectually blocking the passage of a pack-train. Small trees, bearing the buffalo berry (*Shepardia argentea*) and service-berry bushes (*Amelanchier alnifolia*) are found together with them. These latter may serve as a hypsometric guide, occurring in that latitude rarely above 7,000 feet elevation. Another tree that may be utilized in the same way is the quaking-asp (*Populus tremuloides*). It was noticed that this tree, as is the case with all *Salicæ*, is mostly found near moist places, and it is frequently, therefore, regarded as indicating the presence of water. In this we were often mistaken, however, but found that where it grew in dry (temporarily so) places, it invariably selected the northern or northwestern slope of a valley or cañon. Two circumstances combine to render these exposures more favorable to the reception and retention of moisture, the prevailing vapid winds and the absence of sunshine during a considerable portion of the day. Quaking-asp sets in at an elevation of about 7,500 feet above sea-level. In the larger river-valley groves of cottonwood (*Populus balsamifera*) afford excellent camping places. They grow to considerable height, and the bottom of the groves is generally free from underbrush. All the low bluffs and ridges are covered with piñon (*Pinus edulis*) and juniper (*Juniperus communis*). The former bears small nuts in its cones, which are collected by the Indians, and serve as food, either raw or roasted. Neither of these two trees grows to any considerable height, but remains small, with strong, brittle limbs. At about the same elevation yellow pine (*Pinus ponderosa*) occurs in our district, though sparingly. Higher the white pine (*Abies Engelmanni*) is found, mostly only in some of the gulches and ravines leading down from the summit of the Book Cliffs.

Very little tall timber occurs in the district, owing, no doubt, to the comparatively small supply of water. During the time occupied by our work in that region we had very little rain, and in all probability the season was, in that respect, not an exceptional one. Snow during the winter, beginning early and lasting long, supplies in a great measure the moisture for a large portion of the area, which during the summer receives none except that from dew and occasional rain.

It seems improbable that any section of that region should ever be settled, excepting the broad valleys along White River. There, by means of irrigation, fair crops may be raised, that will repay the labor bestowed upon them. Mr. Danforth, Indian agent at the White River Agency, has made some very successful attempts at raising wheat, oats, potatoes, and other vegetables. By demonstrating to his Ute Indians the benefits derived from a comparatively small amount of labor, he has induced a number of them to follow his example. They have obtained very satisfactory results, and were, at the time of our visit, well pleased with the experiment. On the ridges leading to the summit of the plateau and along the watered valleys there is good grazing, and those portions would answer well as a summer-range. Before the completion of the transcontinental railroad a wagon-road was projected and partly completed, following down the White and from the Green River westward, extending to California. It is known as Berthoud's wagon-road. The building of the railroad, however, made an overland wagon-route superfluous, and the work was dropped. Game seems to be abundant in the higher portions of the district, but is very shy.

CHAPTER II.

GENERAL GEOLOGY.

In the district examined during 1876 the variety of geological formations is very limited. It may be well to state that on the east side connection is made with the work of the late Mr. Marvine, which he accomplished during 1874, and on the south with Dr. Peale, 1876; on the west I nearly join with Major Powell, and on the north my northern border was the southern one of Professor White. Fortunately for the peace and happiness of the formations involved, these latter are at all points very characteristic, so that no misapprehensions exist regarding their age.

On the east we find the oldest group, that of the "Red Beds." They are sufficiently well developed, and, as usual, marked in so decided a manner that no mistake regarding their identity could occur, in spite of an entire absence of fossils. To a certain extent they have been disturbed by local plications and faults, although their general trend is in conformity with that of overlying younger beds. In cañons they appear, rarely reaching to the summits of any of the more elevated points, although farther east they no doubt can be found higher up. Superincumbent upon them are the Jurassic and Cretaceous beds. The latter formation is represented by three groups, the Dakota, Colorado, and Fox Hills groups. Of these the first forms prominent hills south and southwest of the agency, showing a considerable thickness. Its distribution is one following an approximate north to south line, parallel to the strike of the strata. Upon this series of sandstones, that retain their well-known characteristics, are deposited the Colorado shales. As usual, these have afforded an opportunity for the formation of deep, narrow valleys, bordered on the east by the Dakota beds and on the west by the Fox Hills group. Owing to their peculiarly "tough" nature, the shales do not permit the water to sink down to any considerable depth, but as soon as the superficial strata are sufficiently saturated the water is forced to flow off, thus producing, in these valleys, streams that are not dry even during the hottest season of the year. At some points the Colorado shales form the base of the long hogback ridge running from the White to the Grand. Above them Fox Hills beds close the Cretaceous. Their vertical development is but inconsiderable as compared to that of Southern Colorado. Throughout the entire formation fossils are rare, save the most common species. This is to be regretted all the more in the upper members of the Fox Hills, as a liberal supply of characteristic fossils would greatly facilitate the accurate definition of the boundary-line between the Cretaceous and the succeeding Post-Cretaceous.

Of the Tertiary formation two groups are represented, the Wasatch and Green River. They follow each other in the regular succession, and are perfectly conformable with each other, as well as with the underlying formations. Although palæontological evidence in these groups is sadly wanting, it has still been possible, from correlation partly,

to determine their geological position. The first group appears but subordinately in the district, but the Green River covers a very large area. It composes the entire mass of the Book Cliffs, and extends northward beyond White River. A gentle northerly inclination of its strata has produced the long, narrow ridges, separated by more or less steep cañons. Readily eroded material composes the beds, and they have offered but slight resistance to the action of water, and, in some instances, ice combined.

Gradually, as our knowledge of the Cenozoic formations of the Rocky Mountains and contiguous areas increases, we are enabled to produce a more definite, more acceptable classification. It is certainly a great temptation to distinguish groups by local names, thus facilitating description and geological chronology, but it leads to confusion, and consequently to inferior value of the results obtained. It will be my endeavor in the subjoined pages to correlate the facts observed with others already known, but to avoid, so far as consistent with the recognition of these facts, the premature acceptance of any local subgroups. In this way only can we eventually arrive at a comprehensive view of the entire series of Cenozoic groups of the West. After once this series has been well established, and its various members have been assigned respectively to their proper positions, then, and no sooner, will be the time to make subdivisions for the purpose of expressing systematic classification—the increased knowledge we have of the subject. Besides Tertiary we find lake and drift deposits in the district. The former are not to be referred to any division of a special period, but merely represent the ancient, perhaps not very remote, existence of lakes at certain localities. Drift occurs as usually along the streams, and in some instances seems to owe its present position to the action of glaciers. This will be discussed at greater length below.

STRATIGRAPHY.

In its general features the stratigraphy of our district is very simple. We have, mainly, a westerly and then northerly dip of the strata, varied only by local folds and flexures. Dr. White, whose district adjoins mine on the north, has there found very important folds, forming continuations of and connections with others far distant. He will treat of them fully in his report which is contained in this volume. At no point, excepting along the Hogback Ridge between the White and the Grand, do any of the folds, observed farther north by him, extend into my district, save for the distance of a few miles only. At the proper place they will be discussed, so far as a discussion of mere fragments is possible. Here mention shall merely be made thereof as to the character and locality of their occurrence.

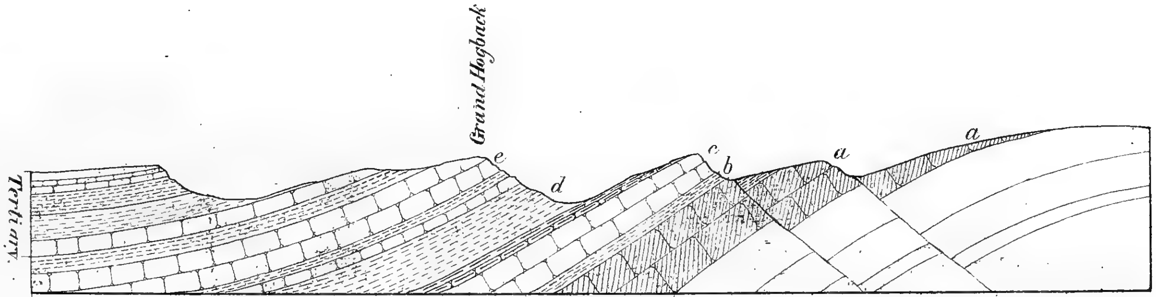
Following along the eastern side of the Hogback Ridge we find that a series of local disturbances have taken place; the most distant results, probably, of serious and extensive folding and plication farther east. They are, however, of but small dimensions, and the vertical dislocations produced have had but little influence in determining the configuration of the region. As a rule, it may be stated that the strata dip westward generally at an average angle of 8°. With the Hogback, however, we find a change. Along its northern end the dip is not much increased, but travelling south we find that it grows steeper. At Station 5, on the drainage of the Grand, the strata stand on end, gradually assuming a gentle dip again, farther west. This is one of those instances that have so often been observed along the Front Range, where the dip in the imme-

diate vicinity of the foot-hills, or mountains, is a steep one; but soon the strata assume a nearly horizontal position again. As we go westward, along the crest of Book Cliffs, we observe nothing but a slight inclination a little west of north, averaging, probably, 2° or 3°. This is constant throughout, from the western slope of the Hogback to the western terminus of our district. No variation can be observed from this general rule until we approach the White River from the south. Here we find the last remnants of those flexures that have been mentioned as occurring in Dr. White's district. About 5 miles below the agency the first instance of this kind is observed. A well-expressed anticlinal fold is cut by the river, and occurs as such for a short distance farther south; is soon lost, however, by a flattening out and subsidence of the disturbed strata. Farther north this is well developed, and forms a prominent feature of the district. Still lower down, on the river, at Raven's Park, another remnant of a most interesting uplift reaches southward across the river. In that park, a level, approximately oval valley, the lower Cretaceous beds are exposed in consequence of having been raised to their present position. On all sides of the valley the bluffs, composed of younger strata, dip off in every direction. Those having an inclination toward the southeast, south, and southwest, fall within the limits of my district, and form a series of rather prominent hogbacks, grouped in an almost regular curve south of the White. From that locality, down the river, no further disturbance was noticed. The general dip, a little west of north, sets in again, and remains constant as far as our explorations extended.

It will be seen, from these remarks upon the general stratigraphy, that the region examined by our party during the season is one which was subjected to but few of the disturbing influences that wrought such thorough changes farther east in the Elk Mountains and west in the Uintas. Whatever action may have produced the plications observed, however extended that may have been, the region south of White River is the one where first again we notice normal conditions of the structure. South of it this continues for some distance until the great folds found by Dr. Peale are encountered. So far as the stratigraphy is concerned, therefore, we have but few and not very extensive exceptions to note, to the evidence of normal, almost undisturbed deposition.

JURA-TRIAS.

Red Beds.—From Marvine's district of 1874 the palæozoic formations extend westward, just reaching the eastern border of our work. The groups forming the area directly east of our section belong mainly to the Carboniferous series. As a rule the dip of the strata is toward the west, but local plications and small faults have produced some disturbances that are of small extent, however. Resting conformably upon the Carboniferous, which does not enter into consideration in this report, are the Mesozoic beds. The series commences with the characteristic group of the "Red Beds," to which has been assigned a Triassic age. In no manner were they observed to differ particularly from those observed on the eastern slope of the Front Range. Most likely their vertical development is somewhat larger here than there, but in all lithological and stratigraphical features they agree closely. Owing to the development of superincumbent Jurassic and Cretaceous strata the Red Beds appear within our district generally in the cañons, and only in some instances do they reach more elevated portions. According to Marvine's survey, the Red Beds cross the White River about 2 miles above the agency,



Section 1.

AM. PHOTO-LITHO. CO. N. Y. (OSBORNE'S PROCESS.

and their western edge follows a southwesterly direction. In 1876 I first noticed them from Station 2, which is located at an elevation of 9,283 feet on Dakota sandstone. There the red sandstones appear in the steep cañons immediately adjacent, showing small local faults. They have a general dip to the westward of about 6° to 8°, which is sometimes varied, however, on account of disturbances. Continuing southward they gradually rise to higher elevations until their highest point within our district is reached at Station 3, an altitude of 9,904 feet. Ridges and cañons extending southward are composed of strata belonging to the same group. In the deep cañons southeast of the station the Carboniferous beds crop out, but are soon covered by younger beds. Farther east, in Marvine's district, Carboniferous strata cover an extensive area, but in our section they appear only as small exposures in the deepest cañons.

From that point on, the Red Beds follow a line of exposure about southeast, parallel in its general course with the Great Hogback Ridge. The sandstones eastward run up high on the slopes of the hills, reaching a thickness there of about 2,000 feet. A section (Section I) taken a little north of Station 2, shows the general vertical distribution of the strata, and a small fault, about 600 feet in height, one of a number occurring in that locality. Massive beds of red sandstone (*a*) are overlaid by a series of grey shales and marls (*b*), interstratified with thin beds of sandstone. These belong to the series that is generally quoted as jurassic and has been so colored on the map. Yellow and whitish sandstones (*c*) of the Dakota Group occur above the light-grey marls, and are in turn covered by the Colorado shales (*d*). Above the latter follow the younger members of the Cretaceous, reaching the Fox Hills group. In spite of the disturbances produced by faulting, the general westerly dip is noticeable throughout, and is in perfect conformity with under- and over-lying strata.

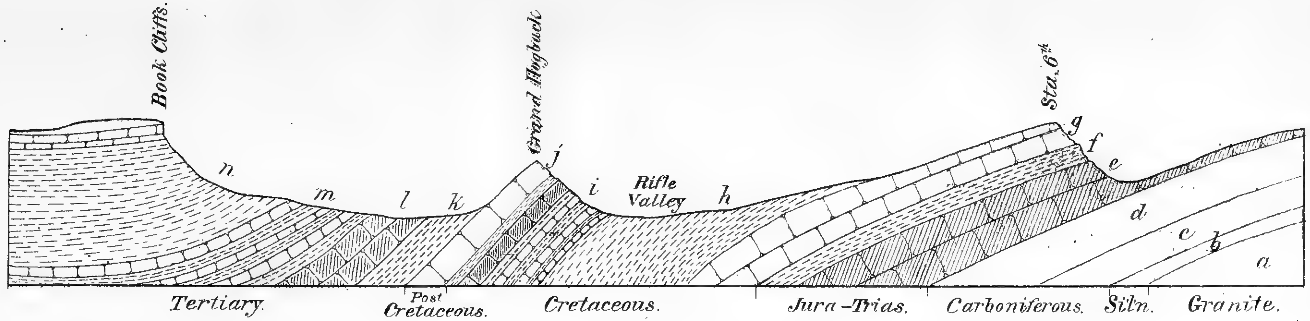
Jura.—Beds that have heretofore, more from their relative position, perhaps, than from any direct evidence, been referred to this formation, occur throughout the entire length of the Triassic outcrop. The beds, composed of light-grey marls, shales, and partly sandstones, overlie the red sandstones, and share with them in the disturbances and faults that have taken place. Along the western border of the Triassic outcrop the Jurassic exposure forms a long narrow strip, extending from the White down to Grand River. No fossils whatever were found in the marls that could furnish any clew as to the geological age of the series. As stated above, their position has been assigned to them long ago, partly on account of some fossils found in the same beds east of the Front Range, partly on account of their position between the Red Beds and the undoubted Cretaceous. It is no more than fair to state that their being placed into the relative position they at present occupy (speaking of both Trias and Jura), is subject to question. Until decisive palæontological proof may have been obtained, either confirming or refuting the opinion now held and expressed, it is necessary to leave room for doubt as to their true position. Lithologically and geognostically they agree very well throughout Colorado, so that they can be readily recognized. Stratigraphically they are almost invariably conformable with older and younger formations, and adapt themselves to the general structure of the region. It is possible that future discoveries may change the views we now hold provisionally with reference to the Jura-Trias, but inasmuch as classification is but the expression of our present knowledge, it is perfectly justifiable that in geological discussions the groups should be separated. It seems surprising that no palæonto-

logical evidence spread over any extensive region has been found within the limits of the Jura-Trias, but we may hope that some day a lucky "find" will reward patient search and set at rest all doubts regarding geological age.

CRETACEOUS.

Of this formation we have several groups represented in our district. Instead of separating the entire series of beds into five numbers, the acceptation of the three groups, Dakota, Colorado, and Fox Hills, is by far more applicable. All of these are developed in their regular succession, and are found at several localities within the district. As usual, they are perfectly conformable to each other, and show the same general characteristics that distinguish them elsewhere. The various groups are more favorably developed in Professor White's district, north of the river; and along the latter, only edges of his Cretaceous areas reach over into my own section. East of and on the Grand Hogback Ridge the greatest development of Cretaceous strata is found. In regular succession the beds follow upon each other, disturbed uniformly by the force that produced the westerly dip. This at times is steep, but soon, true to the hogback character, becomes gentle, and the strata continues in a nearly normal position under the younger Tertiary beds beyond. All the stratigraphical structure is so regular that it will require but very little discussion, and wherever features of any particular interest may be observed, they will be mentioned when speaking of the locality where they were found.

Dakota Group.—True to the usually observable character of this group, it is here also composed of the sandstones and narrow interstrata of dark shales, toward the upper portion of the series. A short distance above the agency the Dakota sandstones cross the river, coming from a more extensive area to the eastward. It forms the prominent hill southwest of the agency, upon which Station 1 was located. From there the outcrop of the sandstone runs a little east of south, opposite the great Hogback Ridge. Near the divide between the White and Grand the Dakota beds form a sharp prominent hill, commanding a good view over the surrounding country. The elevation of this point is 9,283 feet above sea-level, about 1,800 feet higher than the valley immediately west. Following along the outcrop we find that the relative and absolute elevation of the sandstone decreases, and that the higher points are occupied by strata belonging to the Red-Bed series. Cretaceous, then, only flanks the higher hills, dipping steeply toward the west. Farther south, opposite Station 4, the trend of the outcrop of Dakota beds is no longer a southward one, but veers off to the southeast. There too the angle of the dip diminishes, and the area covered by the sandstones is, in consequence, larger than farther north. Station 6 was located on one of the most prominent hills, at an altitude of 8,533 feet. There the dip, in conformity with the change of the line of outcrop, turns slightly toward the south. In the vicinity of the Grand the outcrop gradually becomes more narrow until it crosses the river. In general character the sandstones of this group agree closely with the parallel ones observed elsewhere. Varying from a yellowish white to yellow and even brownish color, they present no change from the *facies* that may be regarded as characteristic of them. Their thickness may be estimated at about 1,000 feet. Among the upper members thin interstrata of dark, partly carbonaceous shales may be observed. They are typical of this upper horizon, and may frequently aid in recognizing the group.


Book Cliffs.
Grand Hogback
Sta. 6th
Rifle Valley
n
m
l
k
j
i
h
g
f
e
d
c
b
a
Tertiary.
Post Cretaceous.
Cretaceous.
Jura-Trias.
Carboniferous.
Sil'n.
Granite.

Section 3.

In every respect are the Dakota sandstones conformable with the underlying and overlying beds, participating only to a slight extent, however, in the local faulting disturbances of the former. It is highly probable that we have but the extreme western traces of the extensive disturbances of the Elk Mountain region. In that case we can assume that the force was no longer sufficient to produce any serious dislocations so far removed from the central point of acting force. Although the general structural arrangement was no doubt occasioned by the agency of this force, it had already been so far spent before reaching the localities in question, that its manifestation there is not a very decided one, regarding local features of structural changes. Along its western edge the Dakota Group is everywhere overlaid by Colorado shales in that region, which latter dip off conformably with them.

This line of outcrop is the only one where Dakota sandstones were met with in our district, if we except a limited occurrence on the White about five miles below the agency. There a slight upward folding of the strata has taken place, and the river has cut through to a sufficient depth to reach the sandstones. They soon disappear, however, being covered by the Colorado shales. To the extreme regularity of stratigraphical structure farther west this complete covering of older beds is due. There has been no opportunity afforded them to appear on the surface within our district either by disturbances or by sufficiently deep erosion where the results of stratigraphical changes farther north have affected the beds in our district.

Colorado Group.—As indicated above, the shales of this group occupy a normal position with reference to the underlying sandstones. They contain, within their area, the valley in which the agency is located, and skirt the hill of Station 1, reaching from the sides of the latter down to the White, thus forming the grassy, gentle slopes which descend toward that river. True to their usual characteristics they here, too, are found developed in a valley. Separating the higher easterly hills from the Grand Hogback Ridge is a valley from one to three miles in width. It is very uniform, scarcely rising perceptibly even at the divide between the White and Grand, near Station 2, and continuing from there downward with Rifle Creek. This entire depression is formed by Colorado shales. It is due mainly to erosion, which must have commenced with the initiative upheaval of the Hogbacks. Along the eastern edge of the valley the shales form low, rounded hills, varying from a dark grey to yellowish and white color. Near the exit of the valley into that of the Grand this feature is especially noticeable. Numerous fragments of *Inocerami* and *Ostreæ* are scattered oll over the hills.

On this eastern side the dip of the shales is generally a steep one, conformable with that of the Dakota sandstones; but as we gradually approach the base of the Hogback Ridge, we find that it diminishes, and the shales dip under the younger beds at an angle of about 6° to 10°. That they, mainly, have given rise to the formation of the valley by more rapidly yielding to erosion, is shown by the fact that along the entire Hogback they reach just about to its eastern base, so that in reality the width of the valley is determined primarily by the relative dip-angle of the Dakota sandstones. Wherever this angle diminishes, the Colorado shale area widens, and thus affords the possibility of a wider valley. It seems highly probable that a number of the low hills composed of these shales were covered by sandstones belonging to the succeeding group, but the cappings have been eroded away, and now only their influence in shaping the horizontal outlines of these bluffs remains as proof of a former existence there. One small bluff was found

still retaining its protecting cap, near the Grand. As is the case with the preceding Dakota Group, the Colorado outcrop follows the same course indicated by the upheaval, or rather upturn, of the Hogback Ridge, and owing to the stratigraphical structure confines itself to a narrow, long strip.

It was a matter of considerable difficulty to make any satisfactory estimate of the thickness of the Colorado shales, owing to the want of sufficiently favorable outcrops. By adding the observations made at a number of localities, however, I have estimated it to about 900 to 1,100 feet, widening, perhaps, and contracting locally. Besides this exposure of the shales, there is but one more in our district. This occurs on the White River, a little east of Station 40, extending from there up-stream about two miles beyond the junction of Douglas' Creek with the White. At that place the shales are exposed in a depression named Raven's Park by Dr. White. They have appeared in consequence of an exceedingly interesting flexure of the strata, which has brought to view them as well as the younger beds, elsewhere hidden from sight by the superincumbent strata of the Green River Group. In speaking of the Tertiary beds the nature of the flexure involved will be discussed. Here it may suffice to say, that the shales are brought to-day and occupy an almost perfectly level valley for about ten miles along the river. Its maximum width south of the White is two and a half miles. Farther north the main depression is found, the one quoted being merely its southern edge. Dr. White, in treating of his district, will speak of it at length.

Fox Hills Group.—Of the three Cretaceous groups, this one certainly occupies the most prominent, topographically speaking, position in our district. In the preceding pages the Grand Hogback has freqently been mentioned. It rises abruptly from the valleys formed by the Colorado shales, shows a steep face toward the east, and falls off more or less steeply westward. Starting along it from the White River southward, we find that its relative elevation is about 1,000 feet; but after we have crossed the divide between the White and Grand, this is increased to 1,600 feet. While north of the divide the ridge is more or less broken by erosion, it presents an almost impenetrable wall farther south. Passages are afforded only by a few openings that scarcely owe their existence entirely to the action of water. Almost the entire Hogback, from the White down to the Grand, is formed by members of the Fox Hills Group. In its northern half, where it is lower, these beds form both the eastern face and a large portion of the western slope, but south of the divide they scarcely reach to the summit. We can assume for the Fox Hills series an average thickness of about 1,500 feet. It begins with dark, soft shales, which are followed by a characteristic white sandstone. This is covered by a succession of grey to yellowish-brown shales, underlying a series of similarly colored sandstones and shales. In the northern half of the Hogback the strata dip westward at an angle of 15° to 18°, but as we proceed south we find that this is greatly increased. At the passage of Rifle Creek through an opening in the ridge, the strata stand perfectly on edge, but assume a westerly dip again, which, in the overlying Tertiary beds, rapidly becomes very gentle. Erosion has produced very striking effects on the eastern slope of the ridge, carving the soft and yielding strata into singularly regular ridges and symmetrical troughs. Cretaceous fossils scattered through the strata composing this group, furnish evidence as to its relative position and age, were those not already furnished by the position occupied. It has been mentioned in speaking of the Colorado Group, that the shales of the latter dip under the Fox Hills beds at the eastern base of the ridge.

We can claim, therefore, for the highest Cretaceous of the region all those strata from the base up to the post-Cretaceous horizon.

The entire Hogback Ridge is structurally an extraordinarily interesting occurrence. Continuing from Dr. White's district into ours, it extends unbroken for a distance of more than 50 miles to the Grand River, and crossing that enters Dr. Peale's district. In its general structure, it is entirely uniform. A dip to the westward is prevalent, varying in angle, however, and at whatever high angle it may be found, soon returning to a lower one. Thus the same beds, that but a short distance from the Tertiary strata, stand on edge, underlie the latter conformably six miles farther west, dipping at an angle of about 4°. These flexures are thoroughly characteristic of the Cretaceous formations of the west; and we have in this instance one, including at the same time post-Cretaceous, and in part Tertiary strata. The connection and correlation of this ridge with continuations both north and south will furnish a clew to the causes for its existence.

On the White, near Station 40, we find another outcrop of the Fox Hills Group, in connection with that of the Colorado shales. It is conformable with the latter, and varies in no particular feature from the group elsewhere, neither in lithological character nor in the arrangement of its strata. With this group the occurrence of Cretaceous beds in our district closes. The area occupied by the formation is a very much restricted one, and one showing exceedingly regular stratigraphical arrangement. The total area covered by Cretaceous beds within our district amount approximately 200 square miles. This is a very small portion of the entire area only, and in consequence of the comparative simplicity of stratigraphical features, the Cretaceous formation there presents but few localities of special interest.

POST-CRETACEOUS.

Laramie Group.—In our district of 1876 it becomes a matter of considerable difficulty to draw the boundary-line between the Fox Hills and the succeeding Laramie Group. Both the upper members of the former and the lower ones of the latter are composed of series of sandstones and shales alternating. In both these groups the sandstones and shales are very similar, so much so that it is almost impossible to draw the line of distinction between the two. The absence of any characteristic fossils is to be regretted, but those that were found certainly do not aid in arriving at any definite decision. Professor White informs me that in his district the circumstances are the same, and that he, as well as I myself, is forced to make a more or less arbitrary division between the two groups. After deliberation I have decided to begin the Laramie with a series of light yellowish to white shales, interstratified partly with sandstones of the same color. These are covered by a series of heavy sandstone strata, separated from each other by grey and brownish shales. These are comparatively constant in their occurrence, and are most typically developed in the southern half of the Hogback Ridge.

The distribution of the beds assignable to this group is very limited. On White River, about fifteen miles below the agency, they first crop out, forming a portion of the bluffs on its south side. From there they continue in a narrow line due south, occurring along the western slope of the Grand Hogback, and below the divide between White and Grand follow the southeasterly bend made by it. The entire horizontal exposure of the group comprises but a narrow strip, although its single mem-

bers are more developed and augmented farther south. While the Laramie beds are found on the west slope of the hogback to the north, they gradually reach to the summit of the ridge which they form on Station 4, at an elevation of 9,311 feet. From there on they continue on the crest of the ridge, participating in the various dips as exhibited by the older underlying strata. Near Rifle Creek they stand on edge, but soon dip more gently, conformably with the Fox Hills underneath. Indications of coal were observed here in the interstrata of dark shales, but at no point were well-developed beds found. North of the agency coal-beds have been found in the same formation, reaching a thickness of about 4 feet. They are located at the southern entrance of Yellow jacket Pass, and have been prospected.

Within our district Laramie strata occur but once more besides at the Hogback, at the same locality where we find the younger Cretaceous beds. South of Station 40 they form a series of low bluffs, the strata of which dip to the southward. There, too, coal was observed, but its quality was not sufficiently good to admit of its use as fuel. It was very "slaty," having a large admixture of shales and marls within the coal-beds. It is quite possible, however, that this is but a local feature, and that good coal, answering all requirements, may still be found in some region where the Laramie Group is exposed. As is the case with the older groups, we find that the steep westerly dip shown along the hogback ridge soon allows the strata belonging to this formation to drop out of sight. They are hidden from sight under the succeeding Tertiary beds, and do not again appear within our district. Though but a comparatively short vertical distance removed from the Tertiary beds that compose the remainder of the area, the extreme regularity of dip shown by the latter excludes the probability of their being exposed in any other than the quoted regions of our district.

TERTIARY.

Groups belonging to this formation extend over by far the greatest portion of our district. More than 3,000 square miles are covered by them. Resting conformably upon the beds of the Laramie Group, they extend westward to the border of the area surveyed in one unbroken mass. In previous pages the structure of the Book Cliffs has been remarked upon. The cliffs proper are no more than the steep southern face of a high plateau which has a gentle slope to the northward. Their eastern border may be said to begin where the slope of the Grand Hogback ends. Occupying, as it were, a neutral position, the strata composing this plateau have been subjected neither to the disturbances emanating from the Uinta Group, nor have those from the Elk Mountains had any appreciable effect upon them. Thus it occurs that the strata are found in a position which is varied from the normal only in so far as they have been subjected to a rise in the southern or a subsidence in the northern portion. They cover all those groups and formations that we have seen pass under them west of the Hogback Ridge.

Two divisions only of the Tertiary are found within the borders of our district, the Wasatch and the Green River Groups. Of these, the latter has been divided into two subgroups by Powell—into the *lower* and the *upper*. I am unable to see the necessity for such division, although it would be a welcome one, so far as the appearance of a geological map of that section of country is concerned. A change takes place in the lithological composition of the strata, but I do not re-

gard that and the results thereby produced as sufficient ground for subdivision. Besides this, I have not found any other feature or characteristic upon which to base a separation.

In speaking of the Tertiary groups below, the older one—Wasatch—will first be discussed, and then will follow the Green River, which comprises very nearly the entire district, and even extends beyond its limits into the regions examined by Drs. White and Peale. Of more interest than the geognostic are the orographic features of this area, inasmuch as they afford an excellent example of the enormous influence that long-continued erosion can produce where it takes place under favorable conditions. The general and even slope of the plateau and the softness of the strata form a combination that must be productive of the most complete results.

Wasatch Group.—Again we begin with the region of the Grand Hogback, as affording the most typical occurrence of beds belonging to this group. A series of low, bluff-like hills, covered with cedars and scattering piñons, occurs west of the hogback slope in the vicinity of White River. They extend northward into Professor White's district. Sandstones and generally light-colored shales compose them, and weather readily into ever-changing forms that keep fresh the colors exhibited by the strata. Continuing in a southerly direction, they gradually get narrower, being encroached upon by the Green River beds setting in from the west. South of Station 4 the minimum width is reached, where the hogback allows the formation of but a narrow valley between itself and the eastern edge of the Book Cliffs. These latter swing around to the southwest soon however, and a comparatively low area of triangular shape is enclosed between them, the Grand River on the south, and the southern end of the hogback. Strata belonging to the Wasatch Group form the bluffs and low tables within this area. Viewed from Station 5, on one of the prominent points of the hogback, southeast of Rifle Creek Cañon, the appearance of the low portion of country thus enclosed is a very characteristic one. Leaning against the steeply-dipping strata of the Laramie Group are the Wasatch beds, which very rapidly lose their steep dip, however, and spread out in narrow ridges, hogbacks, and tables in the valley. Upon first sight the general appearance strikingly resembles that of the Puerco marls in Southern Colorado.* Variegated sandy and marly shales, interstratified with sandstones, form the hills. Colors varying from white to grey, yellowish, greenish, pink, red, brown, and purple, and exhibiting many shades, tend to enliven the monotony of the otherwise dreary scenery at that locality. Piñons and cedars cover the hills, representing the only green vegetation that can flourish in the poorly watered spot. A general dip off from the hogback, *i. e.* toward the southwest, veers more to the west as we approach the edge of the Book Cliffs, and as the Wasatch strata dip under them, they acquire the gentle northerly dip that is prevalent among the Green River beds. All along the base of the cliffs, so far as within our district, the variegated beds may be traced; they cover but a very small area, and most frequently appear only in the lower portion of the precipitous face shown by the cliffs. Dr. Peale has found Laramie occurring there also. I did not observe this latter group within my area, although it is possible that it may exist some distance down the Grand, and there be obscured either by the drift or by the Wasatch beds. Laramie no doubt dips under, together with the Wasatch, but does not appear clearly.

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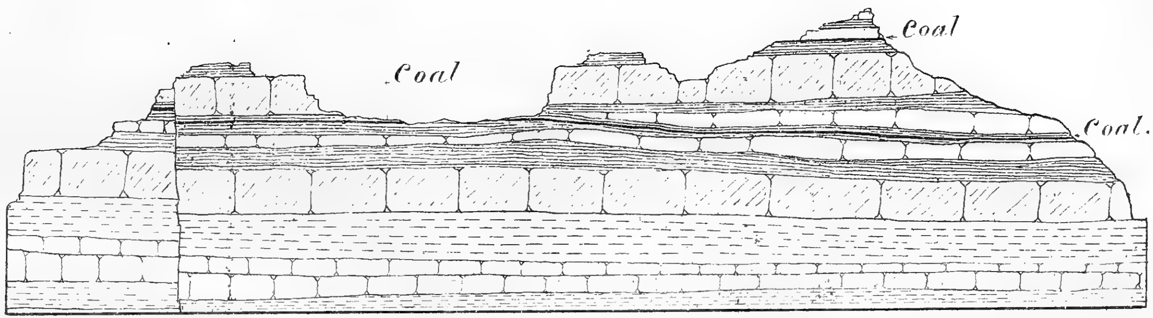
*Comp. Rep. U. S. Geol. Surv., 1875, p. 189.

For a considerable distance along White River, Wasatch beds crop out on the south side, being a continuation of the more extensive development farther north in Dr. White's district. Although comparatively subordinate in their occurrence, they are represented sufficiently to influence the general appearance of the southern banks of the river. Erom there they extend upward into the valleys of a number of the White's tributaries, but are soon covered by Green River beds on account of their dip. Wherever they do reach over into my district their presence is due to some stratigraphical disturbance, the main portion of which is north of the river. At times these disturbances have been productive of very decided changes in the orographical features of the region, greatly confusing the regular system of subordinate ridges and valleys that is so admirably developed farther south. There the regular dip and the average homogeneousness of the strata has produced results that might almost be regarded as schematical in their regularity, both of form and distribution. As soon, however, as any disturbance of this normal condition occurs, this almost ideal arrangement of elevations and depressions at once disappears. Thus, while the topography of our district—one of minimum disturbance—may serve as a model, that of the one adjoining it at the north is by far more complicated.

On White River, near Station 40, is another extensive outcrop of the Wasatch Group. It is the highest of the series that has been brought to exposure by the main upheaval occurring in Professor White's district. In preceding pages the occurrence of Colorado, Fox Hills, and Laramie beds, successively, has been mentioned as existing at the same locality, and we now have to add the last member thus disturbed from its normal position to the list. From a distance already it had been noticed that the strata exposed along Douglas Creek differed in general appearance, color, and shape of hills from those surrounding them. Upon examination it was seen that this was due to the existence of Wasatch beds at that locality. By virtue of the upheaval which has thrown the entire lower series up, south of the river, the Wasatch, together with the others, acquired a southerly dip. As the Green River strata were raised at the same time, subsequent erosions produced an exposure of the former along the lowest portions of the Douglas drainage.

The upheaval itself is a curious one. It has produced an approximately oval arrangement of hogbacks, composed of Fox Hills beds, which dip off from a definite center in every direction. Enclosed by them is a nearly level valley containing Colorado shales. Outside of this inner circle of hogbacks are several others, each one exhibiting the beds of one of the succeeding higher strata. It is owing to this that we find south of the river a concentric arrangement of strata grouped in accordance with their geological age. Professor White will treat of this subject more fully, and I therefore refer to his report for information thereon.

Ascending Douglas Creek we find the exposure of Wasatch beds on either side. They gradually lose their southerly dip, become horizontal, and finally dip northward until they once more disappear under the heavy strata of the Green River Group. Here, too, in the bluffs and the lower portion of cañons, the variations in color, as exhibited by the strata, can be observed, although not so strikingly as in the locality north of the Grand. More particularly one stratum can serve as a well-defined and easily-recognizable horizon. This is composed of a bed of sandstone, about 160 feet in thickness, of a brick-red color. It can be traced from a distance for many miles along the creek, and serves as a landmark for identification. At other localities, contiguous, however, it was also noticed, and then, too, in the same relative position.



Section on Douglas Creek.

Section 2.

AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

A section taken along this creek gave a result which places the thickness of the Wasatch Group of that region at about 1,500 feet. It is possible that in this section some beds may be included that ought properly be referred to the Laramie; but the line of separation cannot be drawn with precision, unless as the result of very careful detail studies. Taking the group as I had determined its vertical extent in the field, we find the following result (*a* being the highest stratum):

(*a*) Yellow sandstones, middle-grained, partly shaly, and containing narrow interstrata of dark shales	180 feet.
(*b*) Dark greyish-brown shales, containing indistinct remains of plants	30 feet.
(*c*) Massive yellow sandstone	60 feet.
(*d*) Shales varying from light yellow to brownish, sometimes almost white with a pink tinge	210 feet.
(*e*) Yellow massive sandstones	130 feet.
(*f*) Grey and yellowish shales, sometimes quite dark, sandy, and containing thin interstrata of sandstones	110 feet.
(*g*) Brick-red sandstone, weathering readily; color constant throughout the stratum	160 feet.
(*h*) Reddish to brown shales	20 feet.
(*i*) Sandstones, partly massive, partly shaly, containing thin interstrata of shales	250 feet.
(*k*) Yellow, grey, and whitish shales and marls	100 feet.
(*l*) Heavy beds of yellow to white sandstones	230 feet.

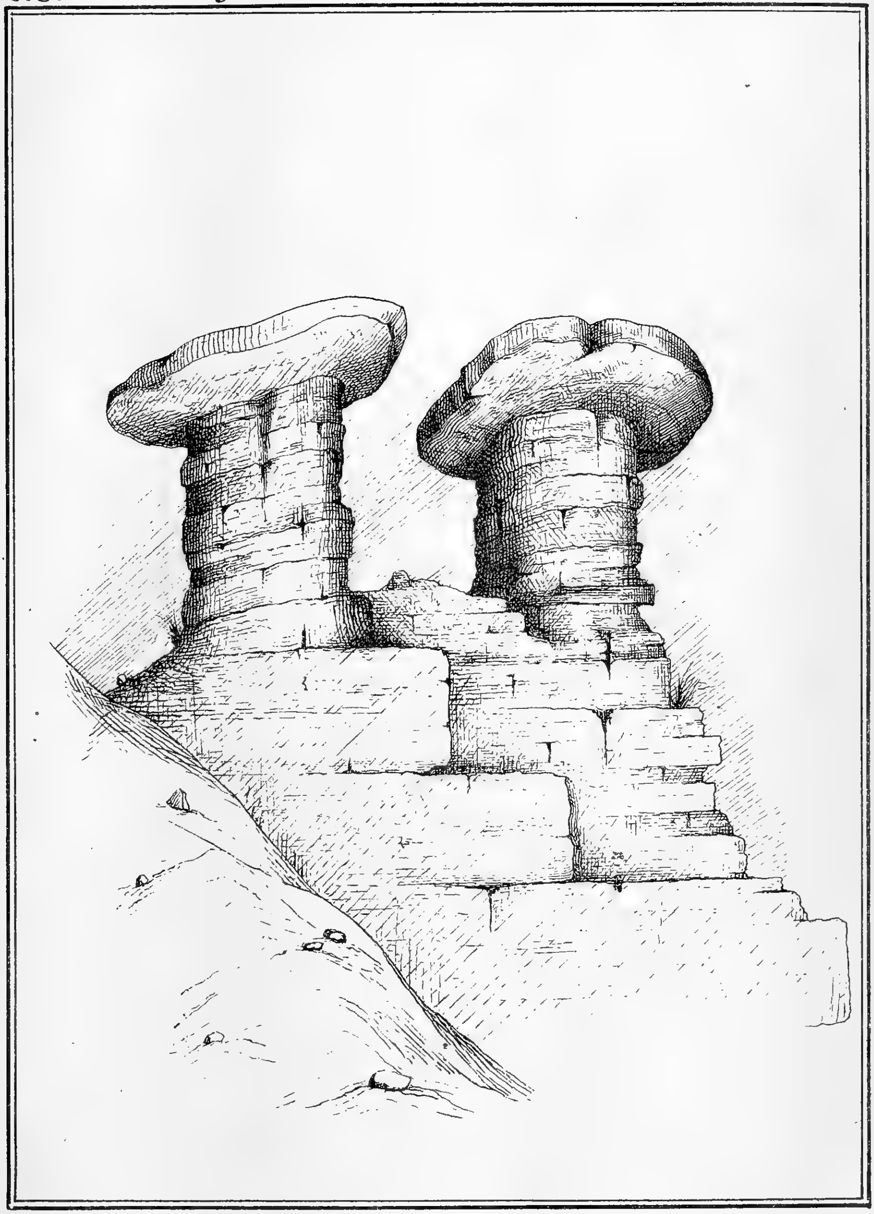
In the upper members of the Wasatch, beds of coal are found within our district. These are not very extensive, however, nor is the quality a particularly fine one. Admixtures of shale make it "slaty," and upon exposure it readily weathers into small fragments. On Douglas Creek, below Station 36, a rather interesting case was noticed, illustrative of the recession and advance of the water into which some of the sandstone beds were deposited. A sketch there taken, and reproduced as a section (Section II), will give an idea of the appearance as shown upon the vertical face of a bluff. A slight fault (*a*) produces a local disturbance at the northern end of the section. It is simply a small drop, which is due, probably, to a subsidence produced by the erosion of some of the underlying strata of shales. Alternating sandstones and shales compose the lower portion of the bluff. One of the former (*b*) underlies a thin stratum of dark shales (*c*), which in turn are covered by a bed of white sandstone (*d*) of varying thickness. Upon this are deposited two strata of coal (*e*) separated by a thin layer of dark grey, carbonaceous shales. From the south the waters again encroached upon the land where the coal was being deposited, and we find a stratum of white sandstone, which gradually thins out northward and finally disappears entirely, above the coal. A similar thinning out of the upper beds can be observed, that no doubt grow much thicker farther south. The connection was broken at the edge of the bluff and the continuation of the strata not visible. Either by a gradual subsidence of the then existing land or by a rise of the waters from the south this effect was produced.

An interesting feature of erosive action was observed at several points within the Wasatch area. The famous "monuments" of the Pike's Peak region will be remembered by every one, and also the causes that led and still lead to their formation. We have in the instances at present under discussion an analogous case. Instead of sandstones forming the base and column of the "monument," we here have

shales. Noticeable throughout all formations composed of so compressible a material as shales and marls are the vertical cleavage planes. These extend through not only the shales, but implicate the beds and interstrata of sandstone or other more compact rocks contiguous thereto. In consequence of these already existing fissures, erosion by water and frost can rapidly accomplish the work of isolation from the main body. Thus we find in the region of Douglas Creek groups of monuments composed of shales, with cappings of sandstones. After the columnar body has been separated from the main mass, erosion by sand and other agents has full sway, and will determine the detail features of the individual monument. Although more rapidly formed, perhaps, than the monuments of the Garden of the Gods, these also have a shorter existence. Atmospheric influences will soon succeed in crumbling down the frail support, and the protecting sandstone will no longer be sustained.

With this, the occurrence of Wasatch beds in my district is exhausted. It is, as that of the preceding ones, but limited. In a great measure this is owing to the regularity of the stratigraphical conditions. Absence of widely-spread erosion from the surface downward causes the Wasatch to remain hidden from sight.

Green River Group.—Perhaps the best exposure of this group within the limits of our district may be found on the steep face presented by the Book Cliffs just north of the Grand River. From the crest of the cliffs to the precipitous edge facing toward the Grand the fall of the summit is about 500 feet, but there it reaches nearly 3,000 feet within a horizontal distance of less than two miles. On this face the best section of the members composing the group may be seen. Regarding the eastern half of the Green River area from a topographical standpoint, we observe a quite curious case. The section lying between White River and the Grand is essentially a plateau, ascending gently toward the south. For about twenty-five miles the rise south of White River is a regular, gentle one. Streams, belonging to the Pi-ce-ance drainage cut through the soft-yielding shales, leaving uniform ridges between them. At that distance, 2,800 feet above White River, the divide between this and the Grand is reached. Although no perceptible change takes place in the stratigraphical arrangement of the strata, we find that suddenly the waters flow in an opposite direction into the Grand. They flow in deep, narrow cañons, that are almost inaccessible. As they continue their southward course, the walls of the cañons become higher and higher. More correctly speaking, the tops of the enclosing walls retain very nearly the same level, while the stream-bed is worn deeper into the strata over which it flows. The southern edge of the northward-sloping plateau reaches to within three miles of the Grand. Where the tributaries of that stream leave their cañons, the latter have walls 3,000 feet in height, while the plateau edge is but 400 feet lower than the divide between the two rivers. We have, therefore, in this instance, one of those peculiar cases which could be explained by the same assumption that Professor Powell claims for so many of his observations in the region of the Colorado River. This explanation asserts that during the period in which flowing water followed approximately the same courses as to-day, the southern edge of this plateau would have been elevated; that the erosive power of the water was more than adequate to the rapidity of the elevation, and that, in consequence, the water maintained its own former level, while the cañon walls grew higher and higher. No doubt this view is a very ingenuous one, and, if applicable anywhere, it would seem that here in these soft shales there was an excellent opportunity for its consummation.



Monuments in Wahsatch Group.

AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

I am opposed, however, for many reasons, to an explanation that would, if correct, necessarily be corroborated by other facts, the existence of which we nowhere observe. I have not had an opportunity to study the localities which Professor Powell has examined. It is therefore not my place to enter into any discussion upon a question of which I am personally acquainted with but one side.

Proceeding westward from this area we reach the divide between Pte-ce-ance and Douglas Creeks. Upon this a number of stations are located, some of them being the most prominent within the district. On the east side of this divide the narrow ridges, separated by steep cañons, gently slope toward Pte-ce-ance. Within a horizontal distance of twenty miles these ridges fall approximately 1,800 feet, retaining a very even angle of slope, however. West of the divide the slope is decidedly precipitous, forming nearly vertical walls from 1,200 to 2,200 feet in height. On the top of the divide we find that the elevation is quite uniform. Station 11 is 9,035 feet above sea-level, while Station 18, seventeen miles farther north, is 8,704 feet high. Continuing along this dividing ridge we approach White River, and there find that it breaks up into a series of radiating ridges which lead down to the stream. In the valley of Douglas Creek we find Wasatch beds, but ascending to the divide west of it are soon within the Green River area again. From the crest of the Book Cliffs northward we pass over the lower portion belonging to this group, until, within about fifteen miles of White River, we meet with the upper sandstones. Here the general configuration of the country becomes more varied. The ridges are no longer so regular both in shape and distribution, and the cañons do not show the same uniform features as farther east. Erosion and atmospheric agents violently attack the sandstone, and it soon yields to the combined influence, producing very unique orographic details. Lithologically the sandstones can readily be distinguished from the older shaly beds of the same group, but a classificatory separation of the two seems at present certainly ill advised.

Stratigraphically the Green River Group in our district is remarkably simple. Its strata partake to a slight extent of the flexures extending southward from the northern more disturbed district, but their effect is soon lost, and the former resume their normal position. As such, a slight dip, varying from 1° to 6° a little west of north may be regarded. It is noticeable wherever the strata are exposed, and only slight variations of the angle were observed. The most prominent of these was found south of the Station-40 Group, where the dip first diminished to zero, and as we neared White River became a southeasterly, and farther west a southwesterly one. Both upper and lower groups are perfectly conformable in this.

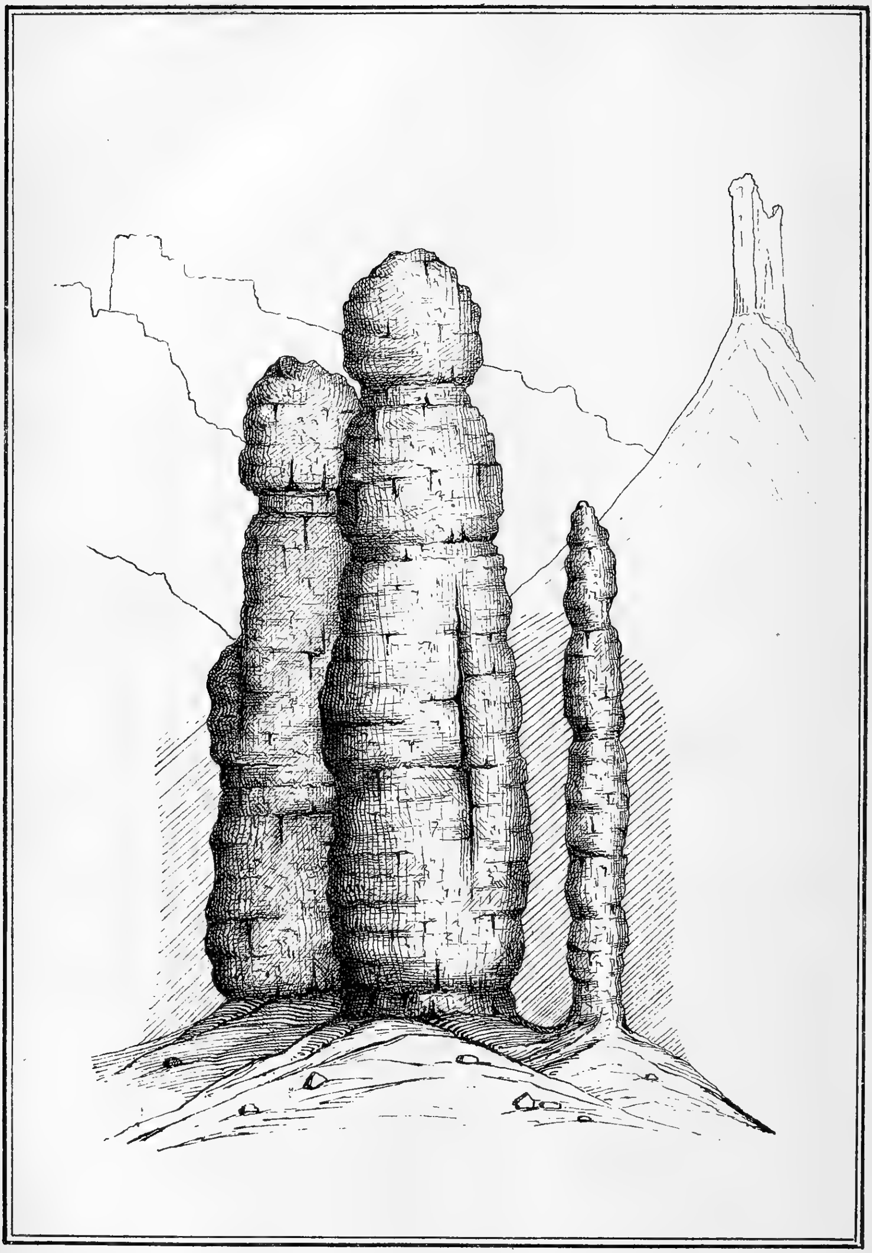
Geognostically and lithologically speaking, we can distinguish the two groups of Powell very readily. While the eastern two-thirds of the Green River area are composed entirely of the shales, the western third contains the younger sandstones. These shales generally show very light shades of color upon exposure, which alternate with narrow, dark bands, thus producing a laminated appearance of the steep bluffs on the faces of which they are visible. Grey, yellowish, and white colors predominate. Subordinate beds of sandstone occur, distributed throughout the shales, but are then so highly argillaceous, that they produce no difference in the general *facies*. Darker bands are usually composed of harder shales. All of them weather, eventually, into thin, chip-like fragments, coated with a mealy clay, the result of decomposition. When freshly broken, the lamination is noticed to be very

finely subdivided; a fact which gives the rocks a pleasing appearance. Erosion produces some exceedingly picturesque effects. Frequently one may ride in a narrow cañon, the walls of which are composed of these hard shales and are 1,000 feet high. Erosion has affected these walls in such a manner that the suspicion of having been utilized as models for architectural ornamentation is almost involuntary. Beautiful carving, dependent upon the superior hardness of certain strata, has resulted in the production of ornamented chancels and long-continued benches, which stud the vertical enclosing cliffs. Long excavations have been worn into the sides of the walls by the action of flowing water, and not unfrequently can the traveller ride in shady coolness for some distance under a protecting natural awning. On the summits of ridges and hills, from where the slopes fall off very steeply or are vertical, the peculiar effect of atmospheric erosion can be studied. Prominent points, the edges of bluffs, or precipitous walls show gracefully-executed carving. It can be compared with the tufaceous deposits near some mineral springs. The soft thin laminæ have been worn away, grooves denote their places, while the innumerable harder ones project like scattered leaves of a book from the wall. All of the forms observed are rounded, so that the total effect produced is that of a deposit formed by overflowing springs. Oxydation of a slight percentage of iron produces changes of color varying from the palest yellow to pink, pale orange, and a light brown, while the remaining strata and laminæ are white and grey. Looking at such a wall from a distance, all these minor details are, of course, lost, and only the main features will be recognized. This character is especially applicable to the highest members of the shale series. Although it certainly exists in the lower portion, it is not so prominent, owing to the occasional admixture and interspersion of arenaceous strata. One of the best localities within the district for the study of these features is along the steep western edge of the dividing ridge between the Pi-ce-ance and Douglas Creeks. In the lower cañon of Evacuation Creek the higher members of the shales reach down to the level of the stream, and there exhibit in the most beautiful manner the effects of erosion as produced by flowing water.

Near the base of these shales we frequently find heavy beds of sandstone, separated from each other by interstrata of shale. The former are generally white or light yellow, while the latter are of a yellow to yellow-brown color. So far as I could observe, the sandstones grow thicker as we proceed westward; it may be, however, that at the points of my observation we had merely a local thickening of the beds.

A large portion of the springs issuing from the shales are alkaline, and almost all the water which flows over them, for even a short distance, partakes of the same character. This is due to decomposition of the constituents of both shales and marls (the latter in the lower portion), which form new compounds, soluble in water. Numerous "alkali-flats" were observed, where carbonates of soda and potash colored the surface as freshly-fallen snow would. Our examinations were made there during the driest season of the year, the most favorable to evaporation, and, therefore, concentration of the alkalies in solution. Several springs were found emitting carbonic-acid gas and sulphuretted hydrogen. They contained ferric compounds and a very liberal supply of alkali in solution. All of them were cold. This feature—alkali-water—is certainly a drawback to many otherwise pleasant regions.

As a total thickness for these shales, including their lower, arenaceous members, about 2,400 feet may be given. This was obtained mainly from the southern bold escarpment of the plateau, and corroborated by



"Happy Family."
in White River Cañon.

AM. PHOTO-LITHO. CO. N. Y. (OSBORNE'S PROCESS.)

observation made throughout the entire group. For the upper laminated shales we may claim of this total thickness 1,000 to 1,200 feet, an estimate which is subject to some local variations.

Above the shales follows a series of sandstone beds, the existence of which can be recognized from a long distance by the peculiar shape which the hills and mountains they compose exhibit. We first met with it on White River, about four miles below the junction of Evacuvation Creek. In color it differs very decidedly from the underlying beds, being yellow and brown with thin interstrata of dark shales. At the locality where we first reached it, it forms the cañon of White River. High walls enclose on either side the narrow valley through which the river winds its way. Erosion attacks the sandstones very rapidly, and produces some of the most singularly picturesque forms. Vertical cleavages, running through the sandstones, aid the destructive power of water and help to form the vertical walls and bluffs that enclose the valley on either side.

This latter is densely covered with a thick growth of willows and other brush. Marching through the valley is greatly impeded thereby. Added to the difficulties offered by the density of the brush is the circumstance that avalanchial drift along the bases of the cañon walls forms almost impassable barriers. The cañon continues, locally widening a little at some places, for about twenty-five miles down the river, to the entrance of Two Water Creek, where it opens a little more. But one creek of any size, Asphalt Wash, dry at the time of our visit, enters the river from the south. On either side of the cañon, the walls of which are 1,000 to 1,200 feet in height, the sandstones have been productive of many fantastic groups, due to erosion and general weathering. Thanks to the vertical cleavages they show, large portions have often been carried away, leaving, perhaps, but a single monument on the summit of a low hill or the brow of a narrow ridge. These out-posts, the forerunners of extensive areas, have a height varying from 50 to 300 feet, and have assumed shapes that a lively imagination can often compare with well-known models of antique statuary. The most frequent form exhibited, perhaps, is one closely imitating ruins of some ancient building or city. Seen by the slanting rays of a setting sun the hills seem fortified each by a castle of enormous dimensions that throws a long-drawn shadow to the eastward. Turrets and battlements are supplied by the skilful hand of nature, that teach by their form the source whence human ingenuity copied them. Cathedrals and spires rise for several hundreds of feet above their gently sloping surroundings, monuments erected to the enormous mass of strata that have fallen beneath the active work of time. Many isolated groups the traveller cannot avoid comparing with domestic scenes, so natural is the pose and distribution of their members. One in particular, within the White River Valley, near Asphalt Wash, showed so affectionate a family picture, that we named it the "Happy Family." It is illustrated by the annexed cut and represented by three isolated columns of sandstone, the largest of which is 80 feet high. It is left to the imagination of the reader to discover the sentiment that prompted a party of explorers to bestow so unscientific a name upon a group belonging to the Upper Green River series.

At Two Water Creek we have arrived nearly at the western border of our district. We traveled up the valley of this stream leaving, for some time, the White. On this river, above the junction of Two-Water, we first found indications of asphalt. Upon examination it was discovered that this mineral occurred in vertical or approximately vertical veins in the yellow sandstones and shales of the Upper Green River beds. The veins vary in width from a quarter of an inch to several

feet. At that locality no springs were found, but the asphalt was hard, brittle, had its characteristic fracture, and upon subsequent chemical examination proved to be very pure. Springs of this mineral were discovered by Mr. Chittenden near the head of Sweetwater Creek, where the asphalt slowly oozed out of the sandstones similar to petroleum in certain regions. This, besides a few beds of limonite, was the only deposit of economic value discovered during the season.

A close estimate assigns to the upper sandstones a thickness of 1,100 to 1,200 feet. They are very uniform in their lithological character, and show but slight local disturbances. South of the White they reach up to the highest points, forming the summits of peaks and the crests of ridges. As we approach toward the divide between the White and Grand we gradually pass upward through the series until about 20 miles south of the river we once more reach the light-colored shales. These continue eastward along the entire divide, and here as there show a surprising constancy of dip as well as of lithological character. Although 125 miles distant from the most easterly exposure, where they were first met with, they in no way show any appreciable change in general characteristics.

Throughout the district, the Green River Group has been a very unsatisfactory one, palæontologically considered. The few fossils that were found were plants and very poorly preserved. Silicified wood was more abundant than any other petrifaction, but of no chronological service. With fossils, the region would certainly have been one of very great interest, although the stratigraphical relations are very simple, but without fossils, without any structural features inviting study, and with the ever-repeated occurrence of the same formations and groups, that extensive Green River area afforded but poor results in return for the work of a geologist. It is essential, of course, that its existence and character in every respect should be determined, as it forms but a link to the great chain which is gradually being completed. Thanks to correlation with other determined horizons and typical lithological character, the Green River Group is readily recognized wherever met with, so that the weight of uncertainty is not added to the disappointment palæontologically.

With this group we close the Tertiary formation of our district, as none of its higher members are developed within its borders. Neither are volcanic rocks occurring there, so that there remains for consideration nothing but the recent deposits.

ANCIENT GLACIERS.

On the White River drainage I have observed no evidence pointing to the former existence of glaciers. The numerous cañons that we find cut through the soft shales, marls, and sandstones, are formed so regularly and agree so thoroughly with the pronounced stratigraphical conditions, that we can scarcely admit of any other agency having shaped them than water. Ascending any one of them toward the main divide, we find that its upward slope is very even, its valley widening wherever other creeks or streams enter, and its entire character in conformity with the view regarding it as the result of the action of flowing water. Primary conditions indicated partly by the present stratigraphical system, have shaped the courses of the streams, but beyond that the results we observe are mainly those produced by flowing water, together with the never wanting atmospheric influences.

In speaking of the Green River Group, mention has been made of the

curious hydrological conditions we observe after crossing the divide between the White and the Grand. It has been stated that even beyond the divide for a considerable distance the plateau continued as such, sloping only very little toward the Grand. In the same distance that the plateau falls about 400 feet the streams cutting through it in that region accomplish a fall of more than 2,000 feet. Had the elevation of the former been the same as now, at the time when the southerly-flowing drainage was formed, this would not have followed the general course it now does, but would have trended off to the east and westward. If we wish to assume, therefore, that we still have the original courses, or an approximation thereof, we must grant to the southern extension of the plateau a considerable dip in that direction. In case, then, that edge had risen, and the streams had cut through each successive stratum as it rose, we would most likely find traces of perhaps even only slight changes in the direction of the flowing water. This we do not. It is difficult to imagine how any stream that is capable of cutting down one stratum after the other in succession, as that stratum attempts a blockage of its downward course, should not, in a thickness of nearly 3,000 feet of beds, meet one that it cannot treat in the same manner. The elevation, probably, was an exceedingly slow one, lasting during a long period of time, but the "accidents" to which the streams would be subject under such circumstances seem to me so numerous, and even formidable, that the absence of any trace thereof is, to me, evidence against this explanation. All the cañons at present under discussion are exceedingly narrow, and they, as well as their smallest branches, show very steep, precipitous sides. From the characteristic detail forms, and from the general character as well, I have come to the conclusion that they owe their present form, in part, to glacial action. No doubt the depressions had been indicated, probably even partly existed, before the moving ice could shape them as we now find them. It is evident that in the soft, readily decomposing material of which the strata consist, no direct evidences of glaciers could have been transmitted for any length of time. Although it is not to be asserted that by glacial action alone the deep gorges were carved out, I regard it as a safe conclusion to assume that in the soft beds of that formation moving ice would have had more direct eroding power than can usually be accorded to it. The minor details and the formation of accessory cañons and ravines may be due entirely to the action of water, but I am of the opinion that its work was greatly facilitated by that already performed by glaciers.

In these cañons the only localities where glaciers may have existed in our district are exhausted. The entire region is neither high enough nor were the conditions of atmospheric precipitation sufficiently favorable in that region for the formation and perpetuation of glaciers.

It is a noticeable fact that at the present time the Grand River drainage within our district is more abundantly supplied with water than that of White River. This, no doubt, is due to the more rapid fall of the streams. Incident thereto is the smaller loss by evaporation and the gradual infiltration into beds composing the sides and bottom of a stream. While we not unfrequently had difficulty in finding water on the White River side of the Book Cliffs, the Grand River slope was well supplied. This in itself would argue in favor of the assumption of glaciers there during former periods.

ANCIENT LAKES.

It seems scarcely appropriate to use the term above given for former lakes within our district, as the impression might be conveyed that they

were in intimate connection with the glaciers. By the term, I merely wish to designate such localities that now are perfectly or nearly dry, while in former times they contained more or less extensive bodies of water. On the maps heretofore published of that section of country the region is generally described as an "elevated plateau with fresh-water lakes and timber." This view argues against the recent dates usually given on the maps, for no lakes have existed there for a long time, geologically speaking.

On the higher portions of the plateau none were noticed as having formerly existed. In a number of the stream-valleys, however, there is proof that at one time quite considerable areas were covered with water that to-day show nothing but drift and soil. Near the junction of the two main branches of the Pi-ce-ance there was formerly a lake of about two to three miles in length, filling the level portion of the valley. Smaller ones were located farther down stream, and are indicated now by the existence of "alkali-flats." On Douglas's Creek, within the area covered by the Wasatch Group, a few small lakes were along the present course of the stream. West of it, on Evacuation Creek, about fifteen miles south of White River, there are beds deposited into a lake of about four miles in length and a mile in width, while lower down similar places are found. At the junction of Bitterwater and Sweetwater Creeks another lake originally existed, but has long since dwindled down to a shallow, highly alkaline pond.

The existence of these former lakes is indicated by several features of unmistakable character. Sometimes (Pi-ce-ance) low benches are formed along the bases of the bluffs inclosing the valley. Generally they are removed, however, being composed of very light material. An exceedingly even distribution of fine sand and silt over a level place, which is surrounded, perhaps, on all sides by abrupt bluffs, furnishes another indication. Not unfrequently will it be found that in such an instance the exit of the stream from the valley takes place through a very narrow opening in the rocks composing the adjoining hills. Swamps, in perfectly level places, where often the stream itself ceases to be definable as such, and small ponds, sometimes remain to mark the spot where at one time water existed in greater abundance. Alkali, deposited by evaporating water, which accumulates in these places during the wet season, occurs regularly at all favorable localities.

It seems possible that most of the lakes were formed merely by an accidental stoppage of the river, either through an accumulation of drift-material or a blocking of some narrow passage. They probably remained for a considerable period of time, which is shown by the enormous amount of silt and sand that has been deposited at those localities, and by the perfect levelling of the *niveau* they once occupied. As a cause for their disappearance I regard the gradual raising of the lake-bed by the constant transportation of sand and silt into the still water. Thus, of course, the level of the water was raised, the horizontal extent of the lake became greater, while its depth diminished, until at last the sheet of water disappeared entirely, either by flowing off or by evaporation. Though occurring quite frequently, the former lakes have water now at but few places. These spots are chosen as favorite resorts by wild water-fowl, and hunting them there is frequently accompanied by great success.

DRIFT.

That species of drift which has been designated as "avalanchial" is found mainly in White River Cañon. We have, in our district, no mountains of any great height, or occurring in isolated groups, where

debris from the slopes could accumulate and form drift. In the cañon above named, however, erosion and weathering has loosened many bowlders and fragments on the faces of the walls, and they have fallen down, forming a sort of talus at the bases of the cliffs. Continuing disintegration would soon reduce them to sand and silt, and their removal would follow were it not for the fact that constantly reinforcements arrive from the same source, which enable the talus to retain its character of avalanchial drift. Along the bases of high Green River cliffs a similar drift may be observed, but its rapid weathering soon destroys it altogether.

River-drifts, consisting of the water-worn bowlders, and sand-bars, we have both in the Grand and in the White. While the latter more frequently contains smaller pebbles and much sand (so far as flowing in the western portion of the district is concerned), the Grand carries large bowlders. Of the White the same can be said for the vicinity of the agency. When it reaches that point, it has just passed through metamorphic, palæozoic, and partly mesozoic rocks, and carries with it the proofs of its course. In some of the broader valleys bordering on the White, we find that this drift has been more or less distributed. This is due to the river's gradually shifting parallel to its own course. The drift carried and deposited by the streams flowing both into White and Grand partakes greatly of the character of alluvial soil. It is mainly a fine-grained soil, containing more or less sand, either uniformly distributed or in single layers and banks. In the valleys of the White River drainage the accumulation of this material is simply enormous. It traverses the valleys from one side to the other, and is sometimes 40 to 60 feet in thickness. Deep gullies are cut into it by every stream coming from either side, a fact which makes travelling very slow. Wherever Indian trails are found they lead over more easily-crossed ravines. The Indians have recognized the difficulty of travelling over so broken a country also, and their trails, therefore, are found on ridges and on the on the divides between main streams.

It is owing mainly to the lithological character of the surrounding rocks that the drift is formed in such enormous masses. All of them disintegrate quite readily, and because of their "tough" character do not so soon lose the argillaceous portions, otherwise we would find but accumulations of sand. Sandstones, shales, and marls, all of these are rapidly eroded, rapidly yield to atmospheric influences, and are easily transported. During the rainy season the creeks and streams, that later are perfectly dry, carry large quantities of water, and carry with them tons of the drift-material. This is deposited in part as soon as the rapidity of the flowing stream is diminished, and in the course of time forms the enormous banks that we observed along the streams. Even in the dry season the White is constantly muddy, owing to the character of the strata through which it and its tributaries find their way. Should water ever be sufficiently plentiful in these localities, the drift just mentioned will furnish excellent arable land. It will naturally be liable to encroachments from the main stream, but arrangements could be made to avoid any serious damage. The question of an adequate supply of water for agricultural purposes along the main tributaries of the White is one, however, that can probably, even now, be answered nagatively.

For the white settler, the region surveyed during 1876 offers but limited inducements. The quantity of water, above all things, is too small to permit of any even approximately dense population, because most likely the country could not sustain it. Good, large timber is rare in the low lands, and the higher regions are too distant to admit of transportation, even could it there be found in satisfactory quantities.

CHAPTER III.

CORRELATIONS OF STRATIGRAPHY, LITHOLOGICAL CONSTITUTION OF STRATA, AND OROGRAPHY.

For a number of years I have paid special attention to the subject, to what extent do the physical constitution of strata and their structural condition influence the orographic features of any given region?

Both in Europe and in the United States I have collected data with a view to presenting at some time a synopsis of the observations made, and to induce from such synopsis the probable results that would be derived from given lithological and structural character. Upon examination, I find that to a great measure the effects from similar or identical causes correspond very well. A recognition of this fact has direct bearing upon the recognition of minor details in mountain ranges and groups. It will facilitate the study of physical geography and frequently afford a clew to the explanation of orographic forms that otherwise might be difficult.

It does not lie within the province of this paper to discuss either the causes by which abnormal positions of strata are produced, or the influence that the action of any plutonic or volcanic activity may have had upon strata or groups. We begin with a comparison of the result produced upon strata or lithological groups by atmospheric and other eroding agents, after they have assumed a rigid stability. Noticing the varying forms, the resultants of similar or identical influences to which each and every one of them has been or is being subjected, we will perceive at a glance the value of a system of reasoning based upon inductive principles. We have analogous, if not absolutely the same, agents producing a multiplicity of results, and by the study of these results can arrive at some conclusion regarding the physical structure and constitution of the media exhibiting them. Indirectly, again, we can, by combining empirical knowledge with the results presented, argue an inference as to the mineralogical and chemical aggregates and constituents composing the forms under consideration.

An application of the knowledge we may derive from the study of cause and effect, the former being almost constant in this instance, will enable us to draw comparatively correct conclusions as regards the general character of the material in which such effect is observed. This is of importance in geological and geognostical work. When in the field, the first intimation of the age or relative position of a stratum may frequently be furnished by some peculiar feature of weathering. If we have for examination before us a circumscribed area, in a portion of which the age and character of the various geognostic horizons have been definitely determined, a study of the exterior physical appearance may often greatly facilitate the recognition of any one of the determined horizons at an even distant locality. No doubt this method is employed almost instinctively by most or all geologists who have occasion to examine regions comparatively or entirely unknown. It is not my purpose, however, to write a "guide for field geologists;" so this instance of direct practical application may suffice.

During four years I have had the opportunity of studying geology in Colorado and a portion of its contiguous Territories. The survey of this State is now completed, and I send forth the subjoined notes with especial reference to what I have observed in that State. Few regions, per-

haps, will prove to be so favorable to the study of "form," both massive and in detail, as Colorado. The former, the massive features, are not considered here, but only the result of atmospheric and other erosive influences upon strata or rocks of different physical constitution and different structural conditions.

All rocks and stratoid deposits can appropriately be divided into four groups, taking their physical characters and their genesis as a basis.

(*a.*) Crystalline aggregates, comprising all those consisting entirely of several crystallized or crystalline minerals, the nature of which determines the species of the rock.

(*b.*) Sedimentary rocks.

(1.) Deposited without the aid of any chemical separation or action whatever. Purely mechanical deposits.

(2.) Deposited with the aid of chemical action. Crystalline at times, consisting of but one mineral.

(*c.*) Eruptive rocks, containing segregated minerals in a paste which may be amorphous or crystalline.

(*d.*) Redeposited, recent material.

This general division with but slight exceptions corresponds in the main to a chronological separation. Instances occur where eruptive rocks, younger than a portion at least of the sedimentaries, consist entirely of a crystalline aggregate. Eruptive granite, which is known to have intruded into Post-Cretaceous strata, is an example of this kind. With such and similar exceptions, however, which at best occur but rarely, the arrangement is essentially one that corresponds with the successive genesis of geological divisions.

CRYSTALLINE AGGREGATES.

As belonging to this group we count Granites, Syenites, Diorites, Gabbro, and Schists. Each one of these is represented by a large number of varieties, determined by the absence or substitution of one or the other constituent mineral. The three first of these are, physically, closely related to each other, while the two last form a correspondingly parallel subgroup. Three varieties can be distinguished of the first subgroup, varieties that are based not upon mineralogical or chemical, but purely physical distinctions, *coarse*, *middle*, and *fine-grained.*

Coarse-grained rocks belonging to this series are by far less able to withstand erosion and degradation than the other two. Frequently either the feldspar or mica may be found to be so arranged as to present its cleavage-plane in one direction mainly. Both of these minerals show large crystals, and it will be a comparatively easy matter for either flowing water, frost, or any similarly acting agent, to destroy in a short time the original shape of the exposed mass. Should even the cleavage-planes not be so arranged as to fall mainly in one direction, the same causes will produce an abrasion which stands in direct proportion to the average size of the crystalline masses, as compared to others. It is evident, therefore, without going into details as regards the process by which the removal of material is effected, that a coarse-grained granite, for instance, will have a tendency to form rounded hills, blunt summits, and rounded edges. In case the crystals lie in one cleavage-plane, frequently small vertical or sloping smooth walls will be formed, which more effectually resist disintegration than the remaining portions. One of the most powerful agents in shaping the minor orographic details is the growing vegetation. Through the growth of roots, the enormous wedging-power of which is well known, particles of

minerals are forced off or loosened, and thus the more rapid erosion by other agents is facilitated.

Diminishing with the size of the constituent minerals are the characteristics above given for coarse-grained rocks of this group. As the former become smaller, the aggregate forms a more compact mass, less assailable by atmospheric influences, water, and sand. Instead of rounded hills we will find steeper mountains, showing sharp ridges leading toward the summit. Abrupt changes of the angles of slope and precipitous edges will denote the more thoroughly resisting material. While here we find higher mountains generally, coarse-grained masses will rarely occupy any very elevated position, being too readily reduced by disintegration. These features, however, can change if we have before us a *stratified* or stratoid mass of rocks. In this case the features of mountains and ranges no longer conform to the synopsis above given, but are subject to the same variations that are characteristic of the next following group.

While the avalanchial drift from coarse-grained granite or kindred rocks generally occurs in more or less rounded bowlders, that of the finer-grained varieties is angular, with sharp edges, and flat instead of rounded sides. If worn by water, the latter will, as a rule, show more regular forms, owing to its greater degree of homogeneousness.

The second subgroup: Gabbro and schists appear as totally distinct from the preceding, if we except the possible bedded condition of the latter. It is a very rare occurrence to find schists lying horizontally. Generally they are tipped up, more or less steeply inclined, and we have in their exterior character the combined influence of a crystalline aggregate and stratified structure. Very rarely are coarse-grained varieties belonging to this series met with. Usually the component minerals are small and distributed evenly throughout the masses. Acicular crystals lying in one direction tend often to increase and subdivide the distinguishable strata or layers. A predominance either of quartz or hornblende enables rocks of this group to resist very successfully the attempted disintegration. For the same reason growing vegetation will not produce so extensive a loosening or removal of fragments as it does in a coarse-grained rock. Flowing water selects for destruction the most readily yielding beds, and leaves others either as partially rounded narrow benches, or broken fragments, denoting the course of the former continuous hard stratum.

Whenever we find the strata inclining or standing on edge we will observe that they form steep, sharp ridges, and very often high peaks. (This latter is due, however, not entirely to the resistance of the rock composing them, but to the fact that this group belongs, as a rule, to the metamorphic series, and its members have acquired their elevated position by virtue of directly active forces.) In that case the slope of the mountains parallel with the dip of the strata is smooth, while the one exposing their edges is generally exceedingly ragged. Dependent upon the angle of the dip and that of the latter slope is the formation of precipices and overhanging walls.

Vegetation has more influence in removing portions of these rocks than it exercises with middle or fine-grained rocks of the first subgroup. This is accomplished inasmuch as the growing roots can more readily enter the narrow crevices between single layers or strata (the former of which are frequently exceedingly thin), and can thereby produce a dismemberment of numerous particles. Avalanchial drift of this subgroup shows characteristics that indicate the bedding of the entire mass, and the more or less frequent occurrence of narrow cracks and fissures.

In accordance with their resistance to decomposing and disintegrating influences, the bowlders show sharp, jagged edges, and abrupt, transverse fractures, besides those parallel to the stratoid arrangement.

As an incidental agent of erosion, moving ice may be mentioned. Its success, as such, is commensurate with the homogeneousness of the rocks over which it passes, and dependent greatly upon the circumstance whether it takes its course over massive or stratified portions. In the former instance, it will produce a planing, a rounding of the rocks subjected to its action, the result obtained being forms that have received the appellation of "*roches moutonnées*." In a similar manner, though not so decidedly, is the movement of glaciers upon other members of these groups demonstrated. Should they pass over the upturned edges of schistose rocks, they will remove more material from the softer strata than from others, and produce "troughs" in case their course be parallel to the strike of the strata. In this respect, as well as in the first, the action of ice and flowing water with its accompanying bowlders is very similar. Where, however, not only the base but the walls of a ravine or cañon are attacked by glaciers, the result is too characteristic to admit of comparison.

SEDIMENTARY ROCKS.

The sedimentary rocks have been divided into two groups, those representing merely mechanical deposit, and others necessitating chemical action. Of these the former is susceptible of subdivision into

(1.) *Conglomerate*,
(2.) *Sandstone*,
(3.) *Shale*, and
(4.) *Marl*.

It depends, in conglomerates, upon their physical properties what result atmospheric and other abrading influences will have. Mainly two varieties may be distinguished, soft and hard conglomerates. Of these the former yield very readily, while the latter resist more successfully. Conglomerates are originally a mechanical deposit of erratic bowlders, of various size, pebbles and sand, cemented either by the latter, by clay, or in rare instances by carbonate of lime or quartz. If sand forms the cement, flowing water, rains, frost, &c., will easily remove it, and the bowlders, at one time held together, will be loosened and carried off. Unless a protecting cap of some kind may prolong the existence of soft conglomeritic masses, they yield in time entirely to destructive agents. Should the conglomerate be a hard one, we will generally find that it contains softer parts, the distribution and shape of which is either irregular or stratoid. These will weather out more rapidly than the remaining portions, and form cavities or gulches, ravines, &c. In that case the hard, remaining rocks will form crags, or irregular masses. As a rule, conglomerates of this character weather in steep slopes. Gradual erosion will carry away more and more of the matrix, until the bowlders contained within it project on the wall or cliff and the latter appear studded with them. Whenever they form creek-beds, we observe that the water rapidly cuts them away, unless, indeed, they be cemented by quartzitic rock or quartz. It is a very rare occurrence that conglomerates are found otherwise than in a subordinate position as regards the structure of a mountain. An exception of this kind may be noted in the Sawatch Range, where a series of conglomeritic beds, 600 to 1,500 feet in thickness, stretches over a very large area of country.

At some localities it occupies the summits of peaks. When found in this position, exposed to the force of atmospheric erosive agents, it weathers in exceedingly rugged and often picturesque forms. Rents and cracks traverse the strata vertically, widening locally into caves and almost complete arches. Allowing the widening of such rents, parallel to each other, to continue, we find that the result is a series of sharp pinnacles, ornamenting ridges and slopes of the mountain. Vertical precipices denote the cleavage, and readily accomplished disintegration of many portions. Frequently, underlying soft strata are removed by the action of flowing water, glaciers or frost, and the superincumbent ones "drop" down, causing the formation of vertical cliffs that have a general resemblance to an amphitheatre.

Should the conglomerate be stratified, its constitution be sufficiently hard to admit of distinguishing the strata, and they have assumed an inclined position, we will find that the results produced by erosion agree closely with those that may be observed in a coarse grained sandstone under similar conditions.

Sandstones can be appropriately divided into two main groups, heavily bedded and thinly bedded, each of which may consist of three varieties, *quartzitic*, *calcareous*, and *argillaceous*. Of these, the first and third are by far more numerous than the second. When in their normal position, *i. e.*, horizontally stratified, all sandstones show similar general results produced by weathering and erosion. Massive beds in that case present comparatively steep slopes, if quartzitic, rounded and more gentle if argillaceous. This is evident from the physical character of the rock. Sandstone is essentially a conglomerate, or *vice versa*, only that the bowlders, &c., it contains are of very diminutive size. Quartz, carbonate of lime, and clay form the cements that bind the small grains of sand together. The more loosely they are combined, therefore, the more readily will the rock yield to disintegrating agents. If a series of sandstone strata is not homogeneous, *i. e.*, most of the strata hard, others soft, and the reverse, we will find, provided we have normal stratification, that "benches" are formed. With the decreasing thickness of the sandstone beds the outlines of hills or valleys formed change from comparatively abrupt to gentle ones, the summits of hills, rarely mountains, are rounded, their ridges obtuse or obliterated, and their slopes curved. With an increase of clay in the rock we observe the same effect.

Into horizontal beds of this group flowing water cuts valleys or cañons of regular shape. Dependent upon the hardness, &c., these may have steep or gentle slopes, both of which will be very similar to each other. Vegetation is, in this instance, a very destructive agent, changing rapidly the minor details of any exposed surface. By disintegrating the sandstone it produces, mechanically, soil, which in turn is frequently removed, showing the rocks to which it owes its present existence in changed and modified forms. Avalanchial and water-worn drift assume shapes that correspond to the physical nature of the strata from which it is derived. Angular bowlders or round cobble-stones denote a hard, strongly resisting rock. If these former are rounded, the latter flat and of oval or round form, we have a soft sandstone.

At many localities the vertical or approximately vertical cleavages in sandstone strata can be observed. These give rise to vertical or very steep bluffs, by the separation of some portions from the main body of the beds.

Wherever the strata are not in their normal position, either inclined or standing on edge, the character they exhibit differs somewhat from

that above given. Again, it is of importance whether the sandstone is a hard or soft one, massively or thinly bedded. As a rule, all sandstones, if their strata are inclined, form hills that show a gentle slope with the dip, a steeper one opposite. Rounded forms prevail, unless, indeed, we have one of those cases where sandstone merely forms the capping of a bluff, overlying more readily-disintegrated rocks. Should the strata stand on end, then they will generally project prominently in narrow ledges, represented sometimes only by isolated "sentinels" that indicate the strike of the stratum. The harder portions, in such a case. will resist eroding influences and remain, while the softer ones gradually disappear, adding, by their absence, to the prominence of the former.

Attrition by sand which is carried with considerable velocity and force by the wind is a well-known agent of erosion that can demonstrate its influence in a region containing sandstones. The results produced by this species of erosion are manifested in the minor details mainly, in rare instances only having much influence upon the general configuration of a mountain or hill.

Argillaceous sandstone gradually merges into shales and marls, so imperceptibly, sometimes, that it is often a matter of doubt whether we should term certain beds shaly sandstones or arenaceous shales. So, too, do the products of atmospheric and aqueous erosion blend into each other.

Shales and marls, interstratified with sandstones, are productive of forms that depend in a great measure upon the character of the latter. If they are hard, weathering but slowly, we will generally find that more or less gently rounded hills are the result, which contain numerous "steps" or benches, each one the result of the greater resistance shown by the sandstone. If this latter is argillaceous, however, and its beds not too thick, the slopes of hills and bluffs will usually be steep, showing an evenly-sloping angle. In that case, a stratum of sandstone most frequently acts as a protecting cap, preserving the underlying shales from further erosion. Vertical cleavage-planes throughout the series of strata produce local precipitous slopes.

Water cuts deeply into the members of this group, producing narrow, steep gullies and ravines. As a rule, their sides are very even, affording a symmetrical profile on a transverse section. Banks of sandstone or dolomitic beds form benches, running along with great regularity, broken where the facility for so doing was afforded by already-existing cleavage fractures or faulted displacements.

Homogeneous shales and marls, *i. e.*, without interstrata of either sandstones or dolomites, assume very characteristic shapes. They erode in regular forms, representing, *en miniature*, the slopes of mountain ranges and ridges. Wherever no protecting cap of sandstone occurs, or where it has gradually been carried off, we can observe in the carving of the shales steep slopes, regular sides, and a disposition of spurs and ravines that would admirably correspond to a model range. Differences of color in that case produce very beautiful effects. Never-ceasing denudation slowly but surely levels these small ridges in the course of time. Wherever the shale-beds have been changed from their normal horizontal position they give rise to the formation of valleys. This is more particularly the case if they are over and underlaid by harder series of strata. The lesser resistance of the shales to erosive agents allows them to be removed more rapidly than the neighboring groups, and particularly flowing water shows its activity. Lateral valleys with steep sides, little more, often, than ravines and gorges, enter the main one, and

the waters they contain aid in shaping and enlarging the latter. Unless the strata are inclined this feature is not so noticeable, because then the valleys are cut in more regularly, and do not follow the strata of the shales, but in preference the dip, which, though scarcely perceptible, generally exists. Vegetation partly preserves, partly destroys, the detail-features of regions where shales predominate. In the former instance it is the small plants that, by their matted roots, protect the easily-disintegrating material from erosion; in the latter it is the large plants that, loosening the shales, render them more readily transportable. As a rule, however, shales are eroded altogether too rapidly to admit of any considerable accumulation of small vegetation on the steep slopes they present, so that they are unprotected against atmospheric and other eroding agents. Owing to the steepness of these slopes, but a small amount of the detritus remains upon them, but rolls or slides down and forms a yielding talus at the base of the bluff or cliff which has furnished the material requisite.

Land-slides, mostly of small extent, occur quite frequently in shales and in shales interstratified with sandstones. They are due mainly to the existence of "water-strata." As such I designate strata or layers of a very tough, impenetrable shale. Water precipitated upon the surface percolates through the fissures, &c., of the various beds, until it reaches a water-stratum. Owing to the physical constitution of the latter, it is prevented from descending farther, excepting at such places where a break may occur in the stratum. The result is that small rivulets of water are formed between the water-stratum and the succeeding bed above it. An inclination of the beds will direct the course of the water. Wherever opportunity may be afforded, the latter will continue its downward course, and wherever the conditions are favorable it will emerge from the side of a bluff or in a valley, in the form of springs. Should the inclination be sufficiently steep, the comparative separation of two strata, by this accumulation of water, will often result in a downward movement of the superincumbent beds, facilitated by the smooth surface which the water produces. It is thus that land-slides are so frequently formed in regions where shales are abundant.

Although the water-strata themselves consist, almost invariably, of shales, they are not confined to any special formation, but are found in all or nearly all sedimentary groups. In sandstone and limestone strata they occur, producing the same results as elsewhere. In a region that is but sparingly supplied with flowing water the recognition of their existence is of great importance, furnishing, as it does, a clew to the localities in which springs may be found. On the faces of bluffs the water-strata are generally indicated by moist horizons, by efflorescence of epigene minerals or by stains produced by hydrated oxygen compounds of iron and manganese. Where the relative position of a stratum of this kind has been established, it will materially aid in the discovery of existing springs, or in the selection of the most favorable localities for wells. Its horizontal extension, of course, is not without breaks and dry portions; but, as a rule, the existence of water may be depended upon at such places, which would afford the greatest facility for the egress of water at the relative niveau of the water-stratum.

Deposited with the aid of chemical action.—To this group belong essentially the limestones and dolomites. They differ in general surface-features from the preceding series. Instead of a purely mechanical erosion, we have here mainly a decomposition, or chemical alteration, and a subsequent removal of such altered portions. General atmospheric agents, more particularly water, have the greatest effect, chemically, upon the

rocks belonging to this group. Flowing water takes advantage of existing cracks and fissures, cuts its way along the most favorable route, and removes large quantities of both kinds of rock. This is the case more particularly when the water contains an appreciable percentage of carbonic acid gas. If horizontally, or nearly so, stratified, the limestone beds will show aqueous erosion commensurate with the greater or lesser density of their structure. Cleavage-planes and cracks produced by undermining result in vertical walls, that not unfrequently are found in limestone-areas. Should the strata be inclined, they will present very much the same features we would find in a calcareous sandstone. Instead of sharp ridges we will then see more gentle slopes, worn away gradually. The crest itself will generally be steep, as will also the slopes exposing the edges of strata.

Vegetation is a powerful agent of decomposition. Not only does it employ the directly-acting mechanical force, which manifests itself during the period of growth, but it also acts as a chemical agent. Experiments have shown that even the most delicate root-fibres of a plant will attack the polished surface of marble, of limestone in general. Thus certain portions—those containing the purest calcium carbonate—will be exposed to more vigorous attacks from vegetation than others containing admixtures of clay and silica, for instance. Thus an inequality of the surface is eventually produced, which will be corrected at the cost of additional transportation of material from the original stratum or strata.

Dependent upon the chemical constitution of limestones and upon their structure is their character as drift. Avalanchial drift can be found showing both the angular and the rounded bowlders. River and other water-worn drift is scarcely characteristic enough to admit of any distinction, if we except the peculiar, sometimes indistinct, grooving upon the pebbles, which is due either to admixture of harder material or to the action of plant-roots. Marble is but a homogeneous crystalline limestone, and its behavior both under direct mechanical and chemical action is entirely in conformity with its physical character.

ERUPTIVE ROCKS.

These can appropriately be separated into four groups:

(*a.*) Massive volcanic eruptions, extending in flows over large areas.
(*b.*) Local massive volcanic eruptions, extending but a short distance.
(*c.*) Volcanic eruptions, in contradistinction to those termed "massive."
(*d.*) Volcanic dikes and dike-systems.

Massive volcanic eruptions are especially well represented in Colorado. Owing to the regularity and extent of the flows we can appropriately speak of volcanic strata. Wherever rocks belonging to this group have been observed they were found to retain the same general character, varied, of course, by local changes in their physical constitution. Serious disturbances of the strata are comparatively rare, confining themselves mostly to local faults. Viewed as a whole, we may say that the rocks of this group resemble sandstones more than any others. Several physical varieties exist, hard, slowly eroding and resisting atmospheric influences for a long time, comparable to quartzitic sandstone; softer, of irregular physical structure, including tuffs, are analogous in behavior to argillaceous and partly calcareous sandstones. Conglomerates are not wanting.

The primary tendency of strata belonging to this group is, to form table-lands. Extending in long-continued flows over softer, less homogeneous rocks underneath, they present a solid, unbroken sheet, which is less readily attacked by erosive agents than other formations would be. Slight variations in dip direct the water-courses, or they are determined by favorable contact-lines with older groups, or follow fissures and subsidences produced by subsequent seismic activity. A more or less homogeneous paste contains several species of segregated minerals in the rocks of this group, and it is the decomposition of these latter that initiates disintegration of the entire mass. Generally the action of atmospheric agents in changing the surface of such areas is an exceedingly slow one, and would be still more so, did not existing fracture lines accelerate the same. The eventual result, as produced by the combined influence of already-formed fissures and by erosion of all kinds, is a double one, dependent, in a great measure, upon the thickness of the volcanic beds. Wherever they are thin, overlying either crystalline or sedimentary rocks, they form more or less evenly sloping plateaus or high lands. In that case they occupy the highest portions of the region, rising at times to isolated hills or mountains which denote the locality of the original outflow. This is entirely changed, however, when we have a thickness of volcanic beds amounting to 4,000 to 7,000 feet. Then we find that erosion has produced narrow valleys, bordered on either side by mountains. Gentle or steep slopes occur in the latter according to the physical character of the material composing them. As in the sandstone areas, we here find that certain strata are harder than others, probably by having been reheated, and they then give rise to the formation of "benches" on the mountain or hill side.

A homogeneous series of flows will produce a regular, pyramid-shaped mountain, the slopes of which show horizontal stratification. Between such mountains the valleys cut down at even inclinations of their sides, unless cañons of separation should set in and produce the characteristic vertical walls. One feature, occurring quite frequently on a grand scale, changes all these results, however. It is columnar structure of the volcanic beds. In that case the easy separation of columns, produced by the action of gradual disintegration and, more particularly, frost, causes them to fall from the face of the mountain and leave vertical precipices, which, by a continuation of this action, slowly recede toward the summit of the peak. Although regularly-formed, well-defined columns are of comparatively rare occurrence, an attempt at such structure may frequently be noticed, and its existence aids greatly the modification of orographic features.

Alternating at some places with these hard strata are other of less durable texture. In certain horizons (speaking of Colorado) flows are found that contain a paste resisting atmospheric influences less successfully. It is more readily attacked, and instead of the minerals it incloses being the first to decompose, the paste disintegrates and the minerals are contained as such in the detritus, from which often good crystals can be obtained. Should a stratum of this description occur on the summit of a mountain or ridge, we will not find the sharp, angular forms of the preceding group, but will observe that they are more rounded, and that the summit itself presents a more or less plateau-like appearance. This is due to the erosion and transportation of the softer stratum to such a depth where a harder one may again be reached, and offer more energetic resistance. Within strata belonging to this group, too, we find caves and tunnels. They are formed partly by a widening of existing fissures, partly by gradual disintegration of loosely cemented

portions. In most instances of these kinds the openings were found to be larger than any portion of the interior.

Erosion by flowing water is productive of approximately the same results in these two groups, having a greater effect in the latter. Valleys of erosion, occurring in a series of "soft" flows, are wider and slope more gently at the sides than the others. In consequence of the unbroken flows, which often extend over many square miles, water collects in slight depressions, which are incident to the gentle dip or due to other causes. In this way numerous lakelets are sometimes scattered over plateaus, which latter are the favorite localities for such occurrences. Where either the shallow basins existing are not of sufficient depth to contain a body of water, or the quantity of the latter is too small to fill them, extensive swamps are formed on the summits of plateaus. Vegetation, wherever the conditions may be favorable to its existence, has a great influence in shaping minor details of orographic features. Many of the varieties of volcanic rocks decompose very slowly, and furnish but little soil for vegetation. This is particularly true of arid regions. Vegetation and moisture combined, however, rapidly break down the first barrier of impenetrability, and then the process of disintegration proceeds steadily. Besides the lack of water, the numerous avalanches along the slopes of mountains prevent, to a great extent, the growth of vegetation. Avalanches—composed mainly of bowlders and detritus, less of snow—form a very prominent feature in all those districts where the volcanic strata exhibit a columnar structure, and where hard, brittle beds are overlying softer ones, more readily eroded. The steeper the mountain-slope is, the farther can the avalanche descend. It destroys, in its course, what vegetation may exist, and by being devoid of soil prevents the springing up of a new growth.

Erosion by glaciers is in proportion to the harder or softer nature of the strata over which they pass. In the one instance they produce but slight modifications of the surface; in the other the effect produced by them aids more decidedly in changing the detail-orographic features. Sand, driven by wind, has considerable influence upon the minor details of mountain-slopes and isolated groups, carving its peculiar rounded indentations into such portions of the strata as may be found to be sufficiently yielding.

Besides these two groups of the massive flow volcanics, we have the tuffs. In their behavior they closely resemble marls. Loosely cemented, they offer scarcely any resistance to erosive agents, and are cut into every variety of picturesque forms. Cappings of solid volcanic material may protect them in places, but wherever they are exposed they exhibit the most grotesque groups imaginable. Creeks and rivers cut deeply into banks that are composed of this material, and by thus undermining superincumbent strata, cause a vertical or approximately vertical dropping of the latter. Tuffs are of local occurrence, but may be counted upon as being met with in the same horizon within a circumscribed area. Conglomerates are not wanting in volcanic areas; show the same characteristics, however, as any others. Conglomerates of sedimentary formations have been discussed above, and what has been said of those is also applicable here.

Local massive eruptions.—These differ from the preceding group in several respects. They do not extend over very large areas, and are not so regularly stratified. As a rule, isolated mountain-groups are thus formed that have no direct connection or relation to any of the existing chains or ranges. Volcanic material has been ejected through one or more fissures or tubes, and for certain mechanical reasons has not spread

in widely-extended flows, but built up a small range or group of mountains. Physically the rocks of this series resemble the unstratified crystalline aggregates more than the volcanics of the first group. In the paste there is contained a by far larger quantity of segregated, crystallized minerals, which causes the lithological character of the rock to resemble that of fine-grained granite more nearly than that of a trachyte. Consequently we find, too, that so far as erosion and the influence of atmospheric agents are concerned, the volcanics of this group closely resemble granite. By their isolated position, however, and in their relations to the topography and orography of the neighboring regions, they are readily distinguished.

Volcanic eruptions.—Volcanic eruptions are so termed in contradistinction to the massive outflows. Within Colorado none were positively determined, and I very much doubt whether there ever will be. The existence or indication of a "crater" built up by the outflowing lava is essential. Cone-shaped mountains are thereby produced, from the centre of which the liquid lava is poured through the main crater and lateral fissures, over a sometimes considerable extent of country. Many of the eruptions observed in Colorado approach these in general character, but are not sufficiently typical to receive even the name. They belong to a different class throughout, and cannot justly be compared to the former.

Dikes and dike-systems.—Among the volcanic formations these are some of the most interesting, both as regards their distribution and the features they exhibit upon being exposed to eroding influences. Dikes show themselves on the surface generally as more or less regular walls, or form narrow, sharp ridges. One occurrence that must be classed among them is that where the material composing them has reached the surface, and, gradually overflowing, has formed coffin-shaped or cone-shaped hills and mountains.

Simple dikes penetrate mainly sedimentary beds, and, upon the gradual removal, by erosion and transportation, of the contiguous beds, they stand out prominently. Disintegration of the hard volcanic rock composing the dike, widening of originally narrow fissures, or removal of certain portions by water, produce breaks in these walls. In that case they may frequently be represented by isolated, columnar masses, the general distribution of which indicates the course of the unbroken dike lower down. Orographically they impart to a region where they are found a peculiar character. Although, as a rule, they stand out prominently, not disturbing the general level of the adjoining beds, they sometimes give rise to the formation of narrow ridges and hogback-shaped hills. This is accomplished either by their protecting from erosion these beds, or by having rendered them more resisting through partial or complete metamorphosis. Isolated knolls and buttes are frequently formed by the remnants of once continuous dikes, of which portions have been worn away to the present level of the region in which they occur.

Dike-systems have by far more influence in determining surface features than simple dikes, and are not unfrequently the original cause of producing prominent hills and mountains. It will generally be observed that a dike-system has either one central starting-point, or one line from which the single dikes emanate. If these are sufficiently near together, or have hardened, by alteration, the media through which they have passed, they will afford ample protection from erosion to the strata they have traversed. Thus every dike will form the crest of a narrow ridge leading toward the central point or line of outflow. In case the dikes

are sufficiently numerous, they may readily form in this manner a mountain or mountain group of considerable height and extent. Added to the "power of preservation" that these dikes have, with reference to the neighboring, more readily disintegrating strata, is the fact that often the formation of the dike-system itself was accompanied by a local vertical upheaval, thus increasing the relative height of the beds which afterward owe the position they retain directly to the influence of the intrusive volcanic material.

Various conditions under which the dike-rock must have cooled, have produced different physical characters. While some of them withstand, most successfully, the atmospheric and other erosive agents, others readily disintegrate by breaking into more or less angular fragments, which are not long sustained at the points of their original occurrence, but, rolling down, form a talus along the base of the dike. The influence of dike-occurrences upon local orographic features is one not to be underestimated. Although apparently unimportant, when seen only in a single representative, they develop the ability of totally changing the face of a region wherever they may be found in sufficient numbers and in the proper arrangement for that purpose.

SPECIAL FEATURES.

As special features the various curious results of erosive agents may be briefly alluded to. Among these we may count—

Caves and tunnels.
Arches and
"Monuments."

Caves may owe their formation to various causes. Prominent among these are subsidences, excavation by chemico-physical agency, and erosion in its widest sense. Only the last-named enters into consideration here. Most frequently such caves are met with in sandstones, volcanic beds, and hard conglomerates. They are due, mainly, to the existence either of strata or locally circumscribed spots that are composed of material disintegrating more readily than its surroundings. Percolating waters penetrate to any depth that has ever been examined, and should they reach such a stratum or portion of stratum which, for instance, was exposed, the action of the water alone, more particularly, however, that of the frozen water, would produce a gradual, successive scaling off of certain parts, until an opening in proportion to the extent of the yielding rock is formed. Adjoining strata will also be attacked, but suffer less than the soft inclosure.

Arches are, in case they are produced by erosion, the most complete form of caves formed by the same agents. It is natural that they cannot occur unless the conditions are very favorable. It is again a softer stratum or portion of the stratum that is attacked. Instead of having the face of a bluff, however, we must have either an isolated group or narrow wall of the rock. Then the susceptible parts are subjected to erosive agents from both sides. Gradually losing more and more material, the wall becomes thinner, until finally the aperture is cut entirely through, and the arch is completed. Subsequent erosion will give it outlines that are in conformity with the original extent of the soft spot. Another method of formation was observed in an isolated block of sandstone, in the centre of which there was an opening large enough to permit the passage of two men abreast. It was there noticed that a vertical narrow fissure traversed the entire height of the huge block. Water accumulating in this fissure had saturated a soft

interstratum, and the succeeding frosts and thaws had eventually produced the arch.

Four kinds of "monuments" may be distinguished. More frequently met with than any others are those composed entirely of sandstone. Then follows the form having a pedestal of shale and a sandstone cap. Monuments eroded from compact conglomerate are frequent in certain localities. One class of occurrences might be termed "accidental" monuments. This last one is composed of some eroded material, capped by a single erratic bowlder, which has its origin sometimes far distant. Aqueous erosion may be considered as the primary impulse toward the formation of such monuments. Detail features are subsequently produced by atmospheric agents, and by sand driven before the wind. All of these forms depend upon having a hard, protecting cap, which will, at least for some time, prevent a disintegration and eventual removal of the more or less regular column supporting it. A great deal has been said and written about the famous groups of Colorado, belonging to this category, so that this brief allusion to their existence must suffice. By their peculiar and picturesque appearance they attract the eye of even a passing traveller, and have, therefore, become justly renowned.

DRIFT.

Water, flowing, has the most pronounced action upon drift. In discussing the latter, avalanchial drift will not be considered, but only that deposited directly by ice or water. So far as the result of erosion is concerned the effect upon the two is essentially the same. Both precipitated and flowing water have a tendency to remove from the drift the smaller portions of detritus and the slight accumulations of clay and sand and silt. Thus the final result would be an accumulation of erratic bowlders, without any sand or clay connecting the single pebbles. As a rule this final result is not achieved, however, because the same water that removes sand and silt from one locality deposits it within the drift-area at another. An accumulation of the smaller drift-particles forms alluvial soil. Here, too, the endeavor is constantly noticeable to remove finer, lighter particles and leave only the heavier ones. Were it not for the unceasing supply from other sources, our alluvial soil would eventually disappear as such. Deep ravines and gorges are cut into the drift by flowing water, and large quantities of it are thereby transported to other localities.

All rocks, upon disintegration and decomposition, partial or complete, form soil, and, dependent upon the lithological constitution of the original rock, this soil may be classified.

CONCLUSION.

With the above report the discussion of my field-work in Colorado is completed. From 1873 to 1876, inclusive, I was engaged in studying the geological features of that State at various localities. During that time about 27,000 square miles were surveyed by the parties to which I was attached. By an excellent arrangement of the field-parties, I was enabled to explore contiguous areas during the three first years. Their extent amounted to about 23,200 square miles. It is evident that thus the work was greatly facilitated. By being able to trace the same formations over so large an area many points in question were cleared up that otherwise must have remained doubtful. Correlations of formations and groups appeared in a more definite light, and were more

readily recognized. Were it possible that the geologist could enter the field with completed maps in his hand, his work might be more thoroughly done, his time could be devoted more satisfactorily to points requiring special investigation, and his results presented would necessarily have a greater value. Wherever topographer and geologist can work in perfect unison, however, this feature of comparative incompleteness can, in a great measure, be obviated.

At this place, at the close of my field-work in Colorado, it may be justifiable to present a brief synopsis of the observations made and deductions drawn therefrom. Much will be but a repetition of what has been stated in the "conclusions" of preceding years. By presenting, however, the sum of the results in a concise manner, a more connected view of the entire subject may be obtained. It is evident that, in spite of the large area covered, many omissions of characteristic features of each formation will occur. In such cases references will be made to the work of others where the wanting members are supplied.

A formidable array of formations presents itself for discussion. Some of them are entirely unique in their character, others offer much difficulty as to ultimate position in classification. Slowly are we gaining definite, applicable knowledge of our Western groups. Instead of being studied as such, their relations to over- and under-lying formations are now a matter of serious consideration. Viewed thus, from a more objective stand-point, there is every promise of a comparatively speedy settlement of questions that have heretofore agitated geologists and others. In the subsequent pages a chronological succession of the formations will be observed. An exception is made in the case of the metalliferous deposits, which certainly have not all been formed at the same geological period.

PROZOIC.

In preference to the word "azoic," I use the term "prozoic." It presents a more ready definition than the former of the idea that it is intended to convey. Many groups of geological epochs are "azoic," but by no means was their genesis, as such, prior to the appearance of life upon the earth.

Belonging to this group we have, in Southern Colorado, quite an extensive series. It comprises gneisses, granites, various schists, and diorites. Of these the first-named appear to be the oldest. Their position as such may be inferred from their relations to the granites, more particularly. Associated with them are micaceous, chloritic, and hornblendic schists; all of these, however, in subordinate quantities, owing their existence, essentially, to the seemingly accidental predominance of the one or other constituent mineral. It often becomes a matter of considerable difficulty to discriminate between prozoic and metamorphic rocks. But few points can be used in evidence for one or the other view, owing to peculiar relative associations. Petrographic characters avail very little, excepting in case we find diorites. By far more varied and of enormous development are the members of the succeeding group.

METAMORPHICS.

Large areas of the districts surveyed are covered by rocks of this group. They represent an almost endless variety. In the reports of each year they have been discussed and their special features have been noted. It is a difficult matter to draw the line of distinction between the preceding and this group. Although, as a rule, the physical characteristics

furnish strong evidence in favor of the one or other assumption, the number of variations, lithologically and structurally, are sufficiently great to produce a certain amount of confusion. As definite and usually well-determined features of metamorphic rocks, we may regard petrographic character in general, recurrence of certain lithological characteristics in the same horizon, partial or complete stratification, and the occurrence of certain minerals within definitely located vertical limits. In several instances localities may be observed where the transition from undoubted sedimentary into metamorphic beds was evident. This, however, must be considered as an exception rather than the rule. Within the districts I have examined, a few cases of this kind were found, and aided materially in interpreting analogous, though not such unmistakable occurrences.

Gneiss may be regarded as the oldest metamorphic rock in the districts examined. Its relative normal position to granite was established at several points. A number of varieties occur, due in part to the texture of the rock, due in part to inclosed accessory minerals. Among these garnets, hornblende, and crystals of feldspar are the most prominent. A diminution or total absence of this latter mineral, which is part of the typical gneiss, causes it to change into micaceous schist. Accessions of hornblende, or chlorite, frequently entirely supplanting the mica, transform the rocks into hornblendic and chloritic schists. Similar to an arrangement observable in the granites, such changes often remain very constant in the same horizon, in proof of the metamorphic character of the lithological group. The older sedimentary formations have, in many instances, furnished material for the formation of gneisses and allied rocks. From the chemical composition of these we can draw, to a certain extent, inferences as to the former unchanged condition of the beds to which they owe their present existence. An incomplete knowledge of the exact powers of the metamorphosing agents, as well as of the manner in which such powers manifest themselves, precludes any argument destined to establish, with certainty, the nature of the rocks before their metamorphosis.

Schists.—Micaceous, hornblendic, and chloritic schists occur, as such, associated with other metamorphic rocks. Frequently they are due to substitution of minerals within the gneiss, but they also are found totally independent thereof. As metamorphics they are the result of changed rocks that in their original condition showed a different chemical composition and physical structure from those furnishing the granites. If a suggestion may be offered, which, however, cannot at present be proved, I would say that argillaceous sandstones form granite. With the decrease or increase of argillaceous matter in the sandstone, the quantity of feldspar in the granite stands in direct proportion. Silicious sandstones form quartzites. Shales, arenaceous in part, are changed into gneisses, and if the quartz in them is predominant they turn into schists. Admixtures of ferric oxygen compounds may result in the formation of hornblendic and chloritic minerals, provided, in the latter case, that magnesia be present. These deductions suggest themselves from the observations made in the Quartzite Mountains, more particularly.

Quartzite.—Although generally quartzite cannot be classed with the metamorphic, but metamorphosed rocks, we have found an instance where it undoubtedly belongs to the former group. In the Quartzite Mountains, enormous quantities of this material form high mountains. A very complete alteration of the original sandstone has taken place, so that now the single fragments resemble very closely pure quartz.

Stratification has been retained in a measure, and were it not for the fact the quartzites there appear to be even older than the contiguous gneisses, schists, and granites, they could readily be regarded as merely changed by some locally-acting force, and not by that which is designated at catogeneous. In all its relations this quartzite agrees closely with the groups above enumerated. It shows varieties, dependent upon admixtures of accessory minerals, and has preserved, though in a changed form, the characteristic of a sedimentary group.

Granite may be regarded as the best represented species of this group. It is both the most widely extended and the one showing the greatest number of variations. Its usual composition, feldspar, quartz, and mica, is changed proportionally by predominance of one or the other mineral, and thus are distinct varieties produced. Accessory minerals, such as hornblende, tremolite, tourmaline, zircon, magnetite, and others impart to it local characteristics that will be found to be constant within certain limits. Bands or zones, almost strata, of specifically different granite may be seen in definite horizons within the heavy, bulky masses composing a range or chain system. These, more particularly, furnish acceptable evidence of the metamorphic character of the rocks under observation. Interbedded, if the term can be used, are not unfrequently gneisses and schists, the latter showing a number of varieties. In the districts which I examined, the metamorphic granites form a very prominent feature. Younger, generally, than the schistose rocks occurring near or with them, they form high, steep ranges or series of smaller ones connected by the same material. In the Quartzite Mountains their genesis could most favorably be studied. There the direct transition from sedimentary beds into typical granite was observed. In case a detail survey could be made of that locality, I am persuaded that the very beds, unchanged and metamorphosed, could be identified. So far as my observations extend, I am inclined to regard a very great portion of granites in Southern Colorado as metamorphosed Silurian, Devonian, and, in rare instances, even Carboniferous strata. These formations have furnished the material which, by plutonic activity, has been transformed into the condition in which we now find it. No doubt much of the pre-Silurian material has been subjected to a treatment attaining the same end, but we have direct evidence pointing to the fact that younger formations also have been utilized. It is not the purport of this paper to enter into details regarding mineralogical constitution of the various granites observed. References thereto will be found in the Annual Reports of the Survey. Gradual or more rapid cooling of the metamorphosed masses has resulted in the production of many varieties. All of these, however, can be recognized as belonging to one great system.

Metamorphics generally form prominent topographical features, easily recognizable, and, as a rule, determining the character of the country. Their behavior with reference to erosive agents has been discussed in Chapter III of this report.

SILURIAN.

In various parts of Colorado, Silurian beds have been observed. They crop out, at lengthy intervals, along the Front Range. In the interior of the State the Silurian formation reaches a greater development. Within the districts I have examined, I found it in 1873 and 1874. The first observed was in the vicinity of the Arkansas River, both north and south of it. Again, it was seen near the Animas River, in Southern

Colorado. In both instances the beds belonged to the Potsdam Group, consisting of Potsdam sandstone and the calciferous series, or portion thereof. Dr. Hayden and Dr. Peale have observed the same formations* in the regions examined by them. They, too, refer the beds to the same groups. Dr. Peale† suggests the existence of the Trenton or perhaps even Niagara Group. He places the total thickness of Silurian strata, as observed by himself, at about 820 feet.

At best, the Silurian of Colorado is of but subordinate importance, as such, in the scale of sedimentary formations. So far as I could determine, it has furnished, in a number of instances, the material for metamorphic rocks. Plutonic activity has so thoroughly changed the original character of the beds, that little more than a guess dare be ventured regarding the former condition of what now we find to be granites, schists, and other kindred rocks. The groups above mentioned have been determined by fossil remains, and their parallelization with beds occurring in the eastern portion of the North American continent is, therefore, well established. Their occurrence farther north of Colorado and their identification within Dakota, Idaho, Wyoming, and Montana, point to a considerable invasion of the western continent during the earliest sedimentary times. It is the Silurian formation, mainly, that can furnish indications as to the distribution of land and water during the period immediately preceding the first well-authenticated appearance of life.

DEVONIAN.

At a number of localities this formation occurs. It becomes a difficult matter to draw closely the lines of separation between both the older Silurian and the younger Carboniferous. Essentially we have in Southern Colorado a very extensive series of limestones, representing the Devonian formation. Interstrata of shales and sandstones occur near the base and near the top. On the Animas the most complete development was observed. At that locality a considerable portion of the Devonian beds had been subjected to metamorphosing agents, together with the Silurian. I am inclined to the opinion that this has taken place in a large number of instances, comparatively speaking, but at present the original beds have so completely lost their identity that they can no longer be recognized. From the imperfect data that could only be obtained with reference to this formation, it is almost impossible to make any comparison of our Western (Colorado) Devonian with Eastern groups. Should any one be suggested, we may find that the large portion will be parallel to the Lower Devonian groups of the East. A prominent feature in the Western Devonian is the intermingling of Devonian with Lower Carboniferous types. This, too, can be observed in those beds usually assigned to the Carboniferous proper.

CARBONIFEROUS.

Into three main groups has this formation been divided. The lowest or oldest one consists of massive beds of limestones. It is followed by a series of sandstones and shales, containing heavy strata of limestone occasionally. A very characteristic red sandstone of great thickness concludes the formation. Within this latter group interstrata of limestones occur. They are fossiliferous and have determined the age of the

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* Rep. U. S. Geol. Surv., 1874, pp. 41, 111, and Rep. 1873, p. 202.
† Rep. U. S. Geol. Surv., 1871, p. 113.

former. Dr. Peale* has recognized a Permian or Permo-Carboniferous division. In my districts I have not observed this. Throughout the State the Carboniferous formation is well characterized by fossils, sufficiently to set at rest all doubt regarding the identity of the groups. It may be noticed that Carboniferous beds have in Southern Colorado been subjected to considerable contortions. Plications of a complex nature, faulting, and overturns denote the exercise of an enormous force. So far as can be determined, these disturbances must have taken place during a period of time subsequent to the deposition of the older Cretaceous beds. Unless it is possible to extend observations over a large area it will be no easy matter to recognize this fact. Carboniferous waters seem to have covered almost, if not entirely, the area occupied before then by Silurian and Devonian deposits. From this it may be inferred that, within the regions under discussion, no appreciable disturbances can have taken place before the advent of the Carboniferous period. Although a large mass of sediment had been deposited before the Mesozoic era, yet plutonic activity seems to have remained almost dormant up to that period. We find very little evidence of any old eruptions which in other continents are not wanting.

A number of ranges are composed largely of Carboniferous strata. Among them the upper group—Arkansas sandstone—forms a very prominent feature. The Sangre de Cristo Range is flanked on either side by beds belonging to this series, and elsewhere similar cases may be observed. Any attempt at parallelizing the Carboniferous formation of Colorado with foreign standards is a thankless task. We have our own peculiar arrangement and cannot readily compare it with any other known.

TRIAS.

Usually the Jura and Trias of Colorado are combined in any description given thereof. After reviewing all available material I have come to the conclusion that it is perfectly justifiable to separate them. A total absence of palæontological remains within the limits ascribed to the Trias is very much to be regretted. Could any characteristic fossils be found, it would set at rest the question of age. Jurassic beds exist in the western portion of our continent, and the only doubt remaining is whether or not the "Red Beds" should be added to the Jura. The total absence of fossils in the Red Beds argues primarily against the fusion. Lithologically, of course, the differences between the two are very great. First of all, this very characteristic led to the identification as Trias.

In case any comparison between the beds of our Western Trias with that of Europe were attempted, we would find that it agrees remarkably well with the youngest member of the same European formation. The "Keuper" of Germany—"Marnes irisées" of France—show the same detail features that we observe in the West. Arrangement of strata, retrographic and chemical constitution thereof are almost identical. It is certainly not admissible to identify formations by their physical characteristics alone. Taking into consideration, however, the superposition of Jurassic beds in connection with such features, the division, once made, may be sustained.

All along the Front Range the Triassic beds occupy prominent, similar positions, until towards the south they no longer appear; west of the Front Range they also occur, but not so continuous as at the locality first mentioned. It appears that at but very few places the Triassic

* Rep. U. S. Geol. Surv., 1874, p. 117.

waters could extend westward of the main axis of the Front Range, but they found ingress at other points. In their lithological character, the strata of the Triassic formation are very constant. So thoroughly complete is this constancy that it is no exaggeration to say that the formation can readily be recognized at a glance.

JURA.

Wherever I observed this formation within my districts, it was invariably associated with Triassic beds. The two are inseparable in Southern and Western Colorado. Were it not for the marked difference in color between Trias and Jura, it would not be easy to distinguish the two from each other. Neither in general configuration of the surface where the Jurassic beds are exposed, nor in the general lithological character, do they present any markedly distinctive features. Instead of dolomitic interstrata, as in the Triassic group, we here have calcareous ones. These at many localities carry fossils in great numbers.

North of Colorado the Jura is by far better developed; its appearance there is more typical, as compared with older and younger formations. No identification with European horizons seems possible. If the comparison may be used, it might be said that the Western Jurassic appears very much as if the remnants, incomplete, of the European standard succession had been utilized in making it up. Within a very limited vertical space our Western Jura contains fossils, the representatives of which in Europe are many hundred feet apart.

CRETACEOUS.

For this formation we accept in Colorado three groups. Experience has shown that over the vast area of that State they can readily be distinguished and remain constant in their relations. So far as palæontological remains are concerned, Colorado has not furnished an exceptionally rich yield. The fossils that do occur, however, are sufficiently characteristic and varied in form to admit of definite classification of the beds containing them. It is not to be denied that generally the horizons in question have been recognized mainly by the aid of lithological features. Acceptable as this may be with regard to any given formation within a restricted area, it is a method liable to lead to erroneous interpretations. It becomes a matter of vital importance, therefore, to determine, as speedily as possible, in how far we are justified in relying upon petrographic characteristics, taking into consideration horizontal and vertical distribution. Although certain shales or sandstones may be found, apparently identical with others well determined, they may and frequently do contain fossils of a totally different geological age. This fact must be remembered and taken into consideration when the groups of the Cretaceous formation are treated of.

Dakota Group.—Usually the members of this group rest directly upon the Jurassic beds. In that case, they are invariably perfectly conformable, partake of the same stratigraphical features, but are set off, if more or less steeply inclined, in the form of hogbacks. In Southern Colorado, however, we find that the Triassic and Jurassic beds are frequently wanting, and then the Dakota sandstones immediately overlie the Upper Carboniferous Group. In such cases stratigraphical conditions occur that closely resemble unconformabilities. Throughout the districts examined, the character of the Dakota Group was a very uniform one. Massive sandstones near its base gradually change

into thinner beds, separated from each other by bands of shale. Near the top of the group thin seams of coal set in. At a number of localities this coal resembles a semi-anthracite. This is due in part to its greater age, in part to the influence of volcanic material that has traversed the beds. As a rule, the Dakota sandstones, if displaced from their normal horizontal position, form prominent features of the landscape. Hard as the strata are, they can successfully resist disintegration, and present an appearance in the hogbacks at once striking and characteristic.

Colorado Group.—This middle group of the Cretaceous is thoroughly characteristic in every respect. Lithologically it is definitely distinguished from all underlying formations, and its fossils are such as to readily admit of identification. It is a noticeable fact that as we proceed southward in Colorado the vertical dimensions of the Colorado Group are subject to change. We there find that the thickness of the beds is by far increased, that the nature of shales is somewhat different, and that altogether the group is a more prominent one than farther north. A striking peculiarity of these shales is the increased dip they show along the edges of any mountain range or chain. It is evident that the gradual rise of the mountains, requiring more surface-area than before the elevation, must have had a very great effect upon the adjoining sedimentary groups. Incident upon this rise is the tilting of the beds. The physical constitution of the shales appears to have been such that they were more susceptible to such influences than the under- and over-lying strata. It may be that a process of mechanical or chemical hydration caused the shales to expand in a vertical dimension, thus producing an effect more than commensurate with the elevation initiating the change of position. On the other hand it cannot be denied that the general appearance of such localities is one that at first glance suggests a depression subsequent to the main elevation. Both causes, perhaps, have combined to produce the result observed.

Near the highest strata of the Colorado Group we again find seams and beds of coal. They are mostly valueless, being too small to be worked.

Fox Hills Group.—With this division the Cretaceous, formation is closed. As belonging to it we count the extensive series of shales and sandstones reaching from the Colorado Group to the "lignitic" beds. Coal is found at several horizons in the Fox Hills Group within Colorado. Good workable beds occur on the Animas and at other places. The group is a characteristic one, retaining what may be termed a "Cretaceous habitat." It is in harmony with the preceding ones lithologically and palæontologically. All of these three Cretaceous groups occupy extensive areas in Colorado, more particularly in the southern and southwestern portions of the State.

POST-CRETACEOUS.

This formation, which may be regarded as the coal-bearing series proper of the Rocky Mountains, has long since been designated as the Laramie Group. For reasons based upon palæontological and other grounds, it is no longer referred either to the Cretaceous or Tertiary formation by some of the geologists who have examined it. It is more in conformity with the progress of geological science thus to regard the Laramie Group as a separate formation than to assign it either to an older or a younger one, with neither of which it sufficiently agrees. Classification in science is but the expression of the summarized knowl-

edge we have of any given subject at a given time. In case, therefore, if we have come to definite conclusions regarding the existing or wanting affinities of a particular group, we can most readily express our convictions by applying to the group the conventional systematic term equivalent thereto. Such I deemed necessary in this instance. Instead of regarding the "Laramie Beds" as simply a group of one or the other formation, I treat it as an independent formation. It possesses its own peculiar characteristics, it brings to its highest development and essentially closes a chapter in the book of geological history.

Within my districts the largest development of the Laramie formation is found in the Raton Hills.* Near Cañon City another outcrop of it occurs, and again I found it on the west slope of the Great Hogback in the White River district. The exposures in Southern Colorado show a far greater vertical as well as horizontal development. There the formation reaches a thickness of about 2,700 feet, and expands over a large area of country. Special features have been described in the various reports. The coal obtained from banks belonging to the Laramie is the "lignite" of the West. In the strict acceptation it is not a lignite, but a bituminous coal, some of which is coking, while other portions or veins are non-coking. For ordinary economic purposes the coal answers very well, and its present employment in this way is satisfactory. Enormous quantities of it are hidden away awaiting but the active hand of the miner, which shall bring it forth and render it subservient to the uses of man.

TERTIARY.

In the districts I have examined in Colorado I have observed two groups of the Tertiary formation. Local deposits of small extent belonging to the Miocene period occur at a few isolated localities. They are in no direct connection with the widely-extended areas elsewhere. At the same time, it becomes a matter of some difficulty to identify them with any particular portion of the synchronous groups. This characteristic will be found to hold good for a large number of the Western Tertiary localized groups. Whenever or wherever the connection between such groups and the extended series of contemporaneous formations can be established they fall into their places very naturally. It is necessary, therefore, to examine, first of all, the correlations of isolated groups, and not at once distinguish them by specific names that only add to subsequent confusion in classification. Those small groups mentioned above as existing in Colorado are altogether too unimportant to be distinguished in any marked manner. The largely extended series of Tertiary beds are sufficiently characteristic in Colorado to admit of regularly taking their systematic position.

Wahsatch Group (*Eocene*).—The largest development of this group occurs in Southern Colorado. In the district of 1875 the Laramie formation is wanting near the Animas drainage, and we here find that the Wahsatch beds rest directly upon the Fox Hills Group. Their lowest strata compose that series which Cope has named the Puerco marls. Above that the alternating beds of sandstone and shale set in. Again, we find Wahsatch in the White River district. It there overlies the Laramie, and is succeeded by the Green River Group. Wherever erosion has carried away the superincumbent beds of younger age, there the Wahsatch protrudes. A remarkable regularity of stratigraphical condition characterizes the beds belonging to this group wherever I have observed it in Colorado. Coal occurs in several members of the

*Compare Rep. U. S. Geo. Survey, 1875, pg. 192.

group. Nowhere have I seen it, however, giving promise of remuneration in case it were worked. No doubt beds may be found within the districts explored that would eventually furnish an acceptable yield, in case the demand for coal should justify their development. So long as not even the coal of the Laramie age is utilized to its full capacity, there will probably be no occasion to seek in the Wahsatch Group for fuel.

Green River Group (*Miocene*).—This group of the Tertiary I have met with in Colorado only along the White River. There it is very typically developed. Great thicknesses of hard shales, of white, yellowish, and greyish color, denoting fresh-water deposits, characterize the group. It has been fully discussed in the preceding pages of this report, and but little remains to be said. During my examinations I have not found the Green River beds so interesting palæontologically as it is in many other regions. There the large number of fossil species found invest the formation with great interest. As is the case with nearly all groups of similar or analogous genesis, certain regions were by far better supplied than others with vegetable and animal life during the period of deposition. Thus we may find that the flora or fauna, as preserved in the shales, may be one of exceedingly great interest at one locality, while but a short distance off, comparatively speaking, there is scarcely a plant or an animal remaining whereby to identify the strata.

With the Green River Group the list of sedimentary formations that I found in Colorado is exhausted. The local deposits termed "lake-beds" more properly belong to the category of drift than of sedimentary formations.

VOLCANIC FORMATIONS.*

In Colorado we find several distinct types of volcanic formations. Through advantageous grouping, their correlation and relative ages can readily be determined. During the first three years of my work I encountered large masses of volcanic rocks of various types. Their recognition was a comparatively easy matter, after a classification had been decided upon. Four main divisions may be distinguished:

Trachorheïtes,
Porphyritic Trachytes,
Basaltoïds, and
Dikes.

Of these the last named is but a varying form of occurrence of any of the preceding divisions. It has, for that reason, been placed at the end of the enumeration, which is in chronological order, with this exception. Each of the divisions will be discussed briefly, and any one wishing additional information upon the subject may be referred to the annual reports and to the shortly forthcoming paper.

Trachorheïtes.—This division comprises the four groups of Richthofen: Propylite, andesite, trachyte, and rhyolite. Though each one of these is well defined and characteristic in itself, it is impossible to distinguish them at all times during the work in the field. Therefore they have been designated collectively by the above-given name.

Propylite, which is the oldest of the series, I have not recognized in Colorado. It may be that it blends too closely into the andesite, or even trachyte, or it may be wanting altogether. It must be stated that all the outpourings of lava in Colorado belong to the type that has been designated as "massive" in contradistinction to "volcanic" erup-

* I am at present engaged upon a paper on the "Volcanics of Colorado." Therein all the correlations and special features shall be set forth at greater length than here.—E.

tion. This will, of necessity, result in producing large areas covered by the same material, and whereas classification of isolated groups might more readily be accomplished, it becomes difficult when the various members under consideration have been able to commingle.

Andesite occurs at various localities, in rather a subordinate position. Its relative position to trachyte is maintained, but its appearance is only local.

Trachyte is the group that claims our attention more particularly. In 1874 I subdivided it into four numbers, mainly for the purpose of facilitating description. Subsequent examinations have shown that the divisions hold good over a very large extent of country, and I have retained them. A very interesting conglomerate occurs in No. 3, which shows that a temporary cessation of volcanic activity took place at that period. As perhaps the most typical development of this group, may be regarded the Uncompahgre Mountains. There the trachytes occur in a thickness amounting to 7,000 feet. The four subdivisions can be readily distinguished, not only by their position, but also by their lithological and orographic features. From the Uncompahgre region this series of trachytes extends southward until upward of 8,000 square miles are covered by it. Occurring, as it does, over so large an area, the regularity of its members is necessarily a surprise. Local features are certainly not wanting that produce slight variations from the "standard," but they are of little consequence. In the highest member of the trachytes (No. 4) the metalliferous veins of the San Juan region occur. They show the same characteristics and same behavior that lodes of other formations exhibit. An analogous case, comparing more particularly the lodes of the lake district, is found in Transylvania.

Rhyolite, the youngest member of the division, occurs quite frequently in Colorado. It may be found superimposed upon the trachyte, or it may occur as some independent outflow. In the great group of trachorheïtes, in Southern Colorado, it is almost invariably superimposed. Its mineralogical constitution does not vary from that observed in rhyolites elsewhere. Some doubt has been felt as to its age relative to basalt. From what I have observed I should unhesitatingly pronounce it to be older. In Colorado the two are rarely found in contact, and then generally in more or less abnormal positions.

Beside the extended area mentioned above, this division covers many miles as more or less isolated groups, generally deposited upon metamorphic rocks, less frequently on sedimentary.

Porphyritic Trachytes.—Distinct in their main features, though allied in many respects, from the preceding division, are the porphyritic trachytes. Dr. Peale has published a very excellent article upon this subject,* which presents views that I fully indorse.

While the trachytes usually form extended flows, and, in consequence, long unbroken benches and plateaus, the rocks of this division are characterized by their isolated position and by their bold, abrupt appearance. Mineralogically, too, they differ, and chronologically are younger than the trachorheïtes. It is possible that the period of their eruption may have been very near that of the rhyolite, inasmuch as the lithological constitution is analogous; and they not unfrequently have found their way through beds of the same age as those usually penetrated by rhyolite. Be this as it may, they are totally distinct, nevertheless. Many of the prominent isolated mountains or mountain-groups of Colorado and adjacent regions owe their formation to this rock. Spanish

* Bull. U. S. Geol. Survey, No. 3, vol. iii.

Peaks, Sierra La Sal, Sierra Abajo, La Plata Mountains, and others are composed of it. In connection with porphyritic trachytes, dikes are very often found that are more typically represented by no other volcanic rock.

Basaltoïds.—In these I count dolerites and basalts, each with their respective tuffs and conglomerates. Of the former but very little can be found in the districts I examined, but the latter are well represented. Almost endless varieties present themselves, each one of which might readily furnish an occasion for the creation of a new rock-species, were they not unmistakably bound together when found *in positu.* Frequently basalts are found covering the trachorheïtes. They unchangingly preserve the same relative position—that of the younger groups. As capping to plateaus and peaks they occur, occupying the most elevated points. The most extensive basalt-series that I have noticed in Colorado occurred on the eastern slope of the southern extension of the Sawatch Range. All along this slope, far into San Luis Valley, the basalt extends in one uninterrupted flow. There, too, it covers trachorheïtes.

In addition to the occurrence as long-continued flows, which may, however, at present be separated into isolated patches, are the local small eruptions of basalt. Cone-shaped or rounded hills, sometimes far from any mountains, protrude through the surrounding sedimentary beds. Basalt, of several varieties, composes them. Again, it is found as dike-material, second in importance to porphyritic trachyte. Most frequently these occur in the younger sedimentary formations, rarely older than the Cretaceous. No doubt they penetrate the older ones, but the causes resulting in their formation did not exist until comparatively recent geological ages.

Dikes.—Dikes are simply fissures in the "country-rock," injected with some material that at one time must have been in a viscous or highly plastic state. Generally, they are filled from below, but they may also receive the material laterally. As a rule, the material filling the fissure resists effectually the influence of atmospheric agents. Gradual disintegration of the adjoining rock causes the volcanic inclosure to stand out prominently, representing essentially a cast for which the fissure was the mould.

Not infrequently the edges of strata forming the sides nearest the dike may still be distinguished on the wall-like projection. Trachyte, rhyolite, porphyritic trachyte, and basalt form the dikes of Colorado. So far as can be judged, many of them were injected during a time when the lava exhibited a very high degree of heat. This is apparent from the metamorphosis which often the adjoining sedimentary beds have been subjected to. Dependent upon the character of the metamorphosed rock this process may render it less liable to disintegration and decomposition. Obviously the eventual result will be that the sides of the dike remain hidden upon removal of the softer adjoining portions, and that a hill, shaped like a hogback will be formed. Not all rocks, however, are rendered more resisting by metamorphosis; on the contrary, many are led to a more speedy destruction thereby.

We do not find only single, isolated dikes, but entire *dike-systems.* Either radiating from one point, or running parallel with each other or forming a net-work, or combining several of these forms, they are capable of producing elaborate orographic results. Taking, for instance, a case in which the passage of the highly fused lava has sufficiently hardened the material through which it passed, we will readily perceive that a radiating arrangement of such dikes must be productive event-

ually of a conical elevation. Thus, too, with all the other forms. Each one will present a characteristic result, incident upon the nature of its surrounding rocks and of the dike-rock itself.

Sometimes the dikes are found to be in direct connection with the main body of volcanics. In that case they simply represent the filling with volcanic material of fissures formed by volcano-seismic action. What the causes may have been that have given rise to the formation of apparently independent fissures must be determined for every individual instance, as neither the formation in which they occur nor the constitution of the dike-rock affords the slightest clew.

The importance of these dikes in shaping many of the minor orographic features is not to be underestimated. Comparatively insignificant, if isolated, a group of them can produce a very marked effect.

METAMORPHOSED ROCKS.

In contradistinction to metamorphic rocks we may class those that have been changed from their original condition by the direct application of *volcanic* heat.

Remelted granites I have not observed in Colorado. According to Dr. Loew they occur in New Mexico contiguous to or enclosed in rhyolite. Conglomerates, sandstones, limestones, shales, and volcanic rocks are the ones most frequently subjected to such action.

Conglomerates are hardened, so that the cement and enclosed bowlders appear as if being of "one cast." Commensurate with the petrographic character of the enclosures is the change they undergo. Proportionate with the heat of the injected lava, and with the conductive power of the rocks penetrated, do we find the extent of the metamorphosis.

Sandstones are most frequently changed into quartzites, limestones into marble, and shales are altered into what mineralogists know as porcelain-jasper. The first and last of these are by far harder, far better able to resist attacks of atmospheric agents than the original rock. Reheated volcanic-rocks are often vitrified, become brittle, and sometimes emit a semimetallic sound upon being struck.

"MONUMENTS."

As a special feature of much interest the different kinds of "monuments" in Colorado may here be mentioned. They may be distinguished according to their method of formation. Four kinds there are, so far as my observations extend.

Every one is familiar with the picturesque forms of Monument Park. Upon a light-colored (white, grey, or yellowish) pedestal rests the dark protecting cap. The entire monument is composed of sandstone. More readily disintegrating and eroded is the supporting column, hard and firm the stratum which furnishes the caps. Rain, frost, wind, driving sand, and other eroding agents are the artists that produce forms striking for their unique beauty. Throughout the region of Monument Park and the Garden of the Gods they occur, visited and admired by the numerous travellers passing that well-favored spot.

Similar to the preceding are those found on Douglas's Creek in 1876. Instead of a sandstone pedestal, however, we here have shale. Weathered away from the edge of the steep bluff it composes, the shale has been carved into isolated columns. To the superimposed cap of hard sandstone they owe their existence. Reared in a comparatively

short space of time, they soon succumb under the combined attacks of their assailants. The frail support of shales ere long grows too weak to sustain the weight of the capping sandstone, and when this has fallen off nothing remains save a small mound of decomposed shale to mark the former existence. Both this "species" and the one above mentioned might be termed *normal* monuments, in contradistinction to the succeeding ones, which are *accidental.*

Near Antelope Park, on a small tributary of the Rio Grande, lies hidden a spot of unequalled grandeur and beauty. Instead of small monuments, at best 12 to 14 feet in height, we here have them rising to 300 and 400 feet. Towering far above the surrounding spruce timber, they lift their weather-beaten heads toward the sky. Thousands of others, that appear as pigmies by the side of giants, stud the entire locality. Precipitous walls, 600 feet in height, enclose, as though guarding them, the wonderful groups here displayed. Arches and gateways of ample dimensions, carved by the skillful hand of nature into projecting walls, permit a distant view that is closed only by the sharp summits of the continental divide. Similar to the spires of ancient gothic architecture do the monuments at places rise in isolated glory, seeming larger even than they really are from their very position. A trachytic conglomerate furnishes the material for these admirable forms. Erosion and abrasion along the steep walls cause some huge bowlder to project. On either side downward the softer portions of the conglomerate are worn away, until finally, as if growing out of the wall, we find the completed monument.

In 1874 still another kind was observed. From an adjoining bluff large bowlders of basalt had rolled down upon a gentle grass-slope. They rested accidentally upon the surface of a very soft trachytic tuff. Rain and temporary streams cut away the easily-yielding material until nothing remained of it but slender columns, 20 feet in height, that bore upon their tops the erratic bowlders which had protected them from total destruction. These two last species I term "accidental," as the physical composition of the conglomerate is certainly an accidental one, and as the last owe their existence purely to the stopping of the erratic bowlders at that particular locality.

GLACIATION.

In the report of 1875 I have given a synopsis of the glacial evidences observed within my districts during the past years. The presence of ancient glaciers in Colorado is made apparent by the existence of moraines, by the grooving, striation, and polish of rocks *in positu*, and by the formation of numerous lakelets. In previous papers I have associated the existence of glaciers in Colorado with that of large lakes and inland seas farther west. Dependent upon the disappearance of these, I have regarded the extinction of the glaciers. Wherever the conditions were favorable, *i. e.*, a good locality for the accumulation of snow and ice offered itself, there we find the traces of former glacial activity. Not unfrequently the arrangement of moraines is perfectly typical, and the rocks, polished and grooved, appear to be fresh as the glacier has left them. Vegetation has not yet sprung up in many of the places where the soil was all carried away by the moving ice. Streams flowing through and from the glaciers (*Gletscherbach* of the Germans) have worn deep channels into yielding rocks, and, often being dammed, have formed glacial lakes.

So far as can be determined, glacial activity existed in Colorado before

the close of the latest volcanic eruptions. It is possible, therefore, that it may have reached into the historical period. According to Major Powell some of the Pai-ute tribes have legends indicating volcanic outflows, and, as has often been suggested, many of our western basalts have a very "fresh" appearance.

Glaciers have not wrought any radical changes in the general configuration of the country. They have modified certain features, have deepened certain portions, levelled others, but they have not, alone, carved deep cañons, or carried away hills and ridges, leaving in their stead level valleys. Much of the drift that to-day we regard as "river-drift" was undoubtedly first removed from the original place of deposition by glacial action. Silt and soil both can be formed by the never-ceasing action of moving ice and water upon rocky material. Carried on by the water these were deposited near the moraines, until eventually once more they were washed away to form soil for arable lands.

DRIFT.

A number of drift-varieties will always be found in a region so diversified as the State of Colorado. We can distinguish, mainly, glacial drift, lake-beds, river-drifts, and avalanchial drift. Of these the first is simply the morainal accumulations. As soon as these have been removed they lose their identity. Lake-beds are the accumulations of finely separated drift in a body of still water. Frequently such drift may be observed occurring in broad valleys, where eventually either the gradual rise of the lake-bottom or changes of *niveau* have permitted the water to flow off. River-drift is the species most frequently met with. That tendency of flowing water, ever to straighten its course, causes it to cover, in time, often a valley of considerable extent. I call this "parallel shifting of rivers." Thus, frequently, an entire valley may be covered by river-drift. Erroneously, this fact has often been explained by the assumption that at some former period the stream was one of far greater breadth than at the present time. Though this is certainly true in some instances, it is a very rare case. Accumulations of drift on one or the other bank of the stream will, locally, change its course. More material will be deposited on that same side; the river will be shifting away from it. Gradually it may have traversed the entire width of the valley in this manner, leaving evidence of its former presence in the drift it has deposited. This feature can admirably be studied near the junctions of large streams.

By the term "avalanchial drift" we designate the ever-moving recent deposits of rock-fragments on the sides or at the base of mountains. Constantly the rocks composing mountains and peaks are disintegrating and rolling down from a more or less loosely joined talus of enormous dimensions. With the character of the rocks composing it changes the nature of the talus. The harder and more angular the fragments the less stable the slope. Decomposition attacks several kinds of rocks very readily, and then a stratum of soil is formed on the talus that permits the growth of vegetation.

SOIL.

The eventual result of disintegration and partial decomposition of rocks is the formation of soil. A very large portion of Colorado is too high for agricultural purposes, so that a majority of the best, most productive soil must necessarily always remain idle. In other localities, where altitudinal conditions are more favorable, the want of an adequate

supply of water prevents success in agricultural pursuits. Were it possible to organize an exhaustive collection of rocks and the soils they produce, make analyses of both, and apply the knowledge gained to chemical agriculture, much of importance and value might be learned. For such purposes a region not yet civilized offers the best field. As soon as any crops have been put in and harvested the original composition of the soil is changed, and examination of such character would no longer furnish the same applicable results. Even within the altitude where crops may be raised, soils from many different rocks can be found in Colorado. By paying some attention to the requirements of plants and the capability of the soils, satisfactory results may in most cases be obtained.

METALLIFEROUS DEPOSITS.

During the progress of my work in Colorado I have had occasion to visit and examine a number of the mining districts of that State. The mineral resources are of an enormous quantity, and constitute, to-day, the main wealth of Colorado. Gold, silver, copper, zinc, lead, coal, and iron are mined. Mineral deposits are scattered throughout the entire State, and new discoveries are annually being made. In 1857 and 1858 the Pike's Peak excitement caused a large influx of prospectors, miners, and adventurers. As usual a large number of them left the Territory in disgust, but others, more reasonable, set to work to gain gold out of the gulches and placers that in those days yielded very good pay. Most of these, then already worked, are now exhausted, and the miners are obliged to seek the precious metals in veins. The districts which I examined are Gilpin County, Clear Creek County, Boulder County, Caribou district, Sunshine district, Gold Hill district, Summit district, the San Juan mines, and the coal mines of Trinidad and Canyon. It is to be regretted that not more time could be spared for each one of these localities, but I hope that at some future date more extensive examination may be made.

GOLD AND SILVER.

Gilpin County.—Nearly all the lodes of this region are auriferous. Central Nevada and Black Hawk are located in the centre of the metalliferous region. Thousands of lodes have been located, but there are comparatively few only worked at present. Pyrite, chalcopyrite, and sphalerite are the chief gold-bearing minerals. Of these the last named generally contains a small percentage of silver. By this time the mines have reached an appreciable depth, and the yield therefrom is satisfactory. Some of them even furnish an unusually large percentage of gold. Amalgamation and smelting are the means employed in separating the precious metals from the ore. In connection with the auriferous lodes Gilpin County has also some that are worked for silver. In that case the metal is contained mainly in galenite and narrow seams or small particles of fahlerz. These lodes are of secondary importance only, as gold is the main mineral product of the county.

Since 1858 the gulches and mines have been worked more or less steadily. Much speculation and mismanagement by incompetent men had temporarily injured the reputation of the mines, but gradually the deeply-rooted mistrust is removed by the proof of their undoubted resources and value.

Clear Creek County.—In contradistinction to the preceding, this county contains mainly argentiferous deposits. At and near Georgetown the most remunerative mines are located. Some of them produce an enor-

mous yield, and many of them may be classed as "very good." Galenite, sphalerite, several varieties of fahlerz and pyrargyrite are the silver-bearing minerals. Quantitatively they occur as enumerated. In the direction of Gray's Peak the ore-bearing "belt" extends, and there we find mines located above timber-line, at an altitude of about 12,000 feet. I may here mention a curious occurrence that has excited considerable comment. In the report of 1873 I alluded to the frozen condition of the ore in the International mine on Mount McClellan, nine miles west of Georgetown. A tunnel has been driven into the side of the mountain for the distance of 140 feet. There it is reached by a vertical air-shaft. It was found that the ore was all frozen from the very entrance of the tunnel to the depth reached at the time of my visit (June 18, 1873). I have learned that the same characteristic holds good to the present day, although much work has since been done. While there I satisfied myself that the frozen condition of the ore was not owing to any draught of very low temperature that might be created by the air-shaft. Various views have been promulgated tending to explain the presence of solidly-frozen masses to a depth of more than 200 feet, but none of them appear to be satisfactory. I presume that we have, in this instance, a case analogous to that of the "frozen caves" of other parts of the world. It may be that some chemical change at present going on in the surrounding rocks causes a diminution of heat. This occurrence is one of very great interest, but it is my opinion that the proper solution of the question cannot be reached except by a series of observations extending over a long period of time. Meteorological conditions, hygroscopic variations at different seasons, as pertaining to the humidity of the rocks, chemical and physical activity of the minerals constituting the rocks and the ore, besides other factors involved, must be taken into consideration before any acceptable theory can be established. Within the tunnel the sight is one of the most beautiful imaginable. Thousands of thin, transparent ice-crystals line walls and roof, reflecting with myriads of sparkling flashes the light of the miner's lamp. It is truly a magical scene, transporting the visitor to the fairy palaces of the "Arabian Nights."

At Idaho a number of silver lodes are worked. They are well developed, and furnish a good yield. Near Empire, in the same county, gold mines are worked to some extent. Throughout both Gilpin and Clear Creek Counties there are scattering locations of lodes at many localities. Many of the gulches are "worked out," but others still afford sufficient pay to tempt the miner. Gulch-work, though physically, perhaps, more severe, has the popular advantage over mining proper that every day or every week the workman can perceive the reward for his labors in tangible gold, without the interference of a mill or smelting-works.

Caribou District.—Mining in this district is comparatively young, as yet. Almost all the ores are typical silver ores, consisting of galenite, sphalerite, fahlerz, argentite, and pyrargyrite, mainly. From the surface down the indications have been favorable, and, as far as developed, the mines show good results. Many lodes have been located, and the mining-camp that at the time of my visit (June, 1873) was in its incipiency is to-day an active one. Further development of the mines already started will no doubt result in very satisfactory returns of the precious metal.

Sunshine District.—In 1874 the first discovery was made by D. C. Patterson. At first the nature of the ore was not fully recognized, but, as numerous other discoveries soon followed the first, that of the Sunshine lode, the great value of the rich ores was soon established. Prof.

J. Alden Smith did much to bring the district to public notice, and showed, by his management of the American mine, the nature and capability of the ores. This region, together with that of Gold Hill, constitutes one of the most interesting and mineralogically important features of Colorado. Instead of finding the precious metals contained in such minerals, classed as "ores" that generally carry them in that State, they are in combination with tellurium, and sometimes iodine. Tellurids of gold or silver, or both, constitute the ores that have become justly famous on account of their remarkably high yield of both these metals. Mineralogically, the occurrences in these districts are not equalled in any other part of the world. In the Sunshine district the ores showed very high pay from the surface down. Decomposition has removed, to a great extent, the tellurium, and we now find either native gold or silver, or an alloy of the two, in the rock. Fifty-five feet was the greatest depth reached (Fair View mine) at the time (October 22, 1875) I visited the Sunshine camp. At that depth the decomposed ores were beginning to turn into solid, fresh ones.

A greater depth has been reached by the Red Cloud and Cold Spring mines at Gold Hill. It may there be observed that the surface-ores soon give way to the undecomposed. Furthermore it is noticeable that with increasing depth other ores, galenite, sphalerite, pyrite, and chalcopyrite set in. These, too, carry very appreciable quantities of the precious metals. Regarding this in connection with the genesis of an ore-bearing vein, we may be led to some definite inferences. All fissures that now we find to be metalliferous lodes were filtered by infiltration—infiltration taken in its widest sense. The constituents, from their character classed as "ores" may have been in hydrothermal or any other liquid solution, or they may have been in a volatile state, gradually condensing as they receded from the source producing their volatilization. In case we follow up this latter view, we will find that it is borne out by evidence. Less volatile minerals, pyrite, chalcopyrite, galenite, and sphalerite, are found only as we reach greater depth in the vein, while the highly volatile tellurium compounds occur in the greatest quantities higher up. This would place the cause of volatilization at an indefinite depth, but not at the sides of the veins. If we, in addition, take into consideration the fact that the Red Cloud and Cold Springs lodes are contact veins on either side of a porphyry-dike, this matter is still further elucidated. Granite is the country-rock, and it is traversed at that point by a porphyry-dike 40 to 50 feet in width. Between this and the granite on either side we find the two veins. It may be observed that whereas small spurs of the veins enter the porphyry from either side, none are found within the granite. It is impossible, therefore, to separate the formation of the lodes from that of the dike. Inasmuch as the material composing the dike was certainly at one time subjected to the action of intense heat, there is no reason why the ores should not have consolidated in the fissures which they reached as vapor.

All of the metalliferous veins occurring in the regions above mentioned are found to be within the metamorphic area. Typically, as veins, they show scarcely any differences. They are at times contact-veins, between, for instance, gneiss and granite; and again they run entirely in the one or other rock. As a rule they may be said to be what are popularly termed "true fissure-veins." Presumably this appellation is supposed to convey the idea that they are "persistent" as to downward extension. In some localities veins occur that cannot be classed among them. In this case we find the orebearing body is but a member of the gneissoid or schistose rock, is conformable with it in

dip and strike. These cases, however, may be regarded as the exception rather than the rule. So far as practical work is concerned, there is no doubt that the ore-veins of these regions are inexhaustible; *i. e.*, they will reach to depths beyond which the miner of the present day cannot penetrate. Improved machinery for supplying deep mines with cool air and controlling the waters may at some future time permit of still deeper workings.

Summit District.—Southwest of Del Norte a number of mines are located in what is called Summit district. The "Little Annie" first drew attention to the place, and soon other mines were opened. Gold is the metal found there. In 1875 I visited the locality and examined it. So far as could be determined, no regularly-defined veins exist there. The entire hill upon which the ore-bearing rock is found seems to be impregnated with mineral matter. This latter is essentially pyrite, occurring in very minute crystals or particles. It is highly auriferous within certain zones, and upon decomposition the gold becomes free. Thus a very satisfactory yield can be obtained by milling the ore. It remains to be established whether the impregnation will continue to be gold-bearing throughout the entire mass. In other regions I have observed similar impregnations of the same mineral, but as no mining was going on there it became impossible to decide as to their merits. Nearly all the mines in Summit district were but in their infancy, and it therefore cannot be stated what their ultimate prospects or probable fate may be.

San Juan region.—During the year 1874 I had occasion to visit the entire San Juan region while accompanying the party in charge of Mr. A. D. Wilson. At that time not all the lodes or even their localities had been discovered. Since we were there the districts on Lake Fork, near Handie's Peak, and others have been organized. Howardsville and Silverton were the centres of all mining operations.

Early in 1860 and 1861 the metalliferous character of the locality had been recognized by Baker, and he led into the country a large party of prospectors and miners. Hardships and Indians, however, succeeded in disbanding them, and many perished. Since that time until a few years ago the region was either forgotten or dreaded. In 1873 the treaty with the Utes, ceding the land, was concluded, and miners flocked from everywhere to the spot of which such exaggerated reports had reached them. Many were disappointed and returned with discouraging reports, but more remained and may ultimately reap the reward of their perseverance. Instead of only Baker's Park, which was the first known, other localities were discovered, and the country was comparatively rapidly settled.

On the Animas Forks, at Howardsville and at Silverton, the greater portion of the locations may be found. When I visited the places (August, 1874), over 2,000 lodes had been claimed, although but few were steadily worked. Galenite, sphalerite, fahlerz, argentite, and pyrargyrite compose the ores chiefly. Silver is almost exclusively the metal obtained, and occurs in large quantities in some of the veins. An exception to this rule occurs in Arrastra Gulch, near Silverton, where the Little Giant mine is worked for gold. Chloride of silver is reported as occurring in some of the Devonian limestones near the Animas River. I did not have time to verify this report. As is the case with by far the majority of ore-veins in Colorado, so these, too, have a dip almost or entirely vertical. This may certainly be regarded the normal for the lodes of the State. Within the last three years lodes have been found and opened in the vicinity of Lake Fork. Besides the usual silver ores,

tellurides of gold and silver occur there that greatly increase the value of the ore. Settlements have sprung up with the rapidity usually observed in new mining countries, and a region that, but a few years ago, was a wilderness, to-day shows ample evidence of the enterprise and industry of the pioneer miner.

All the ore-bearing veins of the San Juan region, as well as those of the Summit district, lie within the trachorheïtic area. We have in this instance veins that, in their physical and mineralogical character, cannot be distinguished from those of the older formations, occurring in volcanic rocks of Tertiary age. The unusually rugged and broken configuration of the country facilitates mining operations. Not unfrequently metalliferous veins may be traced for several hundred feet of vertical distance on the steep, rocky slope of some mountains, or in the walls of a cañon. Obviously such conditions must be favorable to the miner, assuring him at once of the presence of his ore for a certain distance, and pointing out to him a ready method of extraction. Up to the present time the development of the San Juan mines has been retarded by the want of available capital. The individual miner, however industrious he may be, cannot by his own physical labor properly develop a mine.

A word may be said with reference to the treatment of Colorado ores. Naturally, the first method employed was that of crushing the ore and saving the gold by raw amalgamation. This process is the one requiring the minimum of preparation, one that every man of average intelligence can readily become familiar with, and furnishes to the miner his weekly or monthly product in the shape of bullion. So long as surface-ores—*i. e.*, of gold—were the only ones treated in this way, it answered very well. As soon as the undecomposed ore was reached, the results were no longer found to be satisfactory. In that case the only reasonable method is smelting. Thereby the gold, that otherwise will often go into the tailings and perhaps be lost altogether, can be saved. The sooner this fact is fully appreciated, and the more the smelting processes are brought into harmony with established laws of chemistry (which is not always done), the better will the miner find himself repaid for his hard and dangerous work. A number of good smelting-works have been established in Colorado, and they are fully able to take charge of the ore that may be furnished them, with advantage to the smelter and profit to the miner.

Small placers occur at several places in the districts I have examined. Some of them are worked at present; others have lain idle for years, and still others are exhausted. In and near Taylor River Park, in Greyback Gulch, on the North Fork of Rio Alamosa, and elsewhere, a little work is carried on.

COPPER, ZINC, AND LEAD.

These metals are gained in the extraction of gold and silver ores. They are so abundant, associating with the more precious, that they can be regarded only as a secondary consideration. Some of the smelting-works devote either a portion or their entire force to their extraction. In that case the metals are mostly obtained from low-grade gold and silver ores. Uranium, occurring in pitchblende, was mined in the Wood mine, near Nevada. The yield was satisfactory. At present the mine lies idle, but it is to be hoped, if only for the sake of mineralogists, that work may ere long be resumed. With mineralogical "treasures" of such a nature Colorado is well supplied; less, perhaps, as regards number of species than so far as size and beauty of those occurring are concerned.

COAL AND IRON.

Coal occurs in Colorado at a number of localities; it is found, with interruptions, along the eastern base of the Front Range, and in the interior of the State in valleys of many of the larger streams or their drainage. In 1873 and 1875 I visited the coal mines of Canyon and Trinidad, which lay within the borders of my districts. At both places I found an ample supply, and found mining-operations going on. About the quality of the coal much has been said and written. It is useless to repeat anything here; the object of this paper cannot permit it. Suffice to say, that for ordinary economic purposes the coal will answer very well. An almost unlimited source of coal may be developed in Colorado if all of its available beds are developed. Many years must necessarily pass, however, before this will be required. A brief reference may be made to the "anthracite," which has often been reported from this State. So far as the observations of geologists of this survey go, the anthracites are either older (lowest Cretaceous) coal than the "lignites," or they owe their anthracitic composition to the passage of volcanic material through the beds or seams. In this latter case the heat of the volcanic rocks has caused a partial volatilization of the gases, thus greatly increasing the percentage of fixed carbon. It is evident, therefore, that although we may have an anthracite in the strict mineralogical application of the term, we have not an anthracite in the same sense of the word as it is applied, for instance, to the Pennsylvania coal.

Iron is found and mined in Colorado on Grape Creek, near Canyon City. The ore is magnetite, yielding a high percentage of the metal. But little demand for iron exists in the State at the present time. Should the demand arise, however, numerous deposits, now undisturbed, will furnish ample material to meet it. Limonites occur as kidney ore within the same beds that contain the coal, and if undecomposed, they are siderites. At Golden, Canyon, and Trinidad they are found, and can readily be utilized if required. In the interior of the State certain formations usually carry lower-grade iron ores, which may, at some future day, perhaps, be turned to account.

In order to present a brief synopsis of all the formations found in Colorado, I have prepared a table. In it is recorded not only my own work, but extracts have been made from the reports of Dr. Hayden, Dr. Peale, Mr. Holmes, Mr. Marvine, and Professor Lesquereux. It is at all times a matter of considerable difficulty to attempt parallelization of formations or groups. A certain amount of latitude must be admitted for all comparison of such nature. Though but a comparatively small proportion of the formations and groups can be found in any one particular district, the total exhibit is one showing a sufficient diversity.

Thicknesses of beds and groups have been given, showing the limits that were therein observed. It is evident that over an area of nearly 70,000 square miles great variations of the vertical dimensions must occur, and therefore they have been indicated so far as feasible.

Enumerations of locality are made, beginning with the more westerly ones and going eastward.

Synopsis of the geological formations found in Colorado.

					Locality.	Fossils.	Character of strata.	Thickness of strata in feet.
CENOZOIC.	TERTIARY.	MIOCENE.	*Green River Group.*	Upper Green River Group.	White River....	Leaves on divide between White and Grand. (See Dr. Peale's Report following.)	Massive, dark brown sandstones. Slight interstrata of dark shales. Sandstones weather in very grotesque groups.	1100
				Lower Green River Group.	White River....	....	Extensive shale-series. Near the bottom some sandstones occur. Throughout the remainder of the group the strata are composed of thinly laminated, white, gray, and yellow shales. Some of the strata are much harder than others and form prominent ledges. The group continues southward across Grand River, and is therefore not quoted from that locality.	2000
		EOCENE.	*Wahsatch Group.*		Rio San Juan region...	....	Heavy beds of yellow and brownish sandstones near base. Alternating sandstones and arenaceous shales higher up and to top.	1200 to 1400
					Animas River..........	....	Massive beds of yellow sandstones. Interstratified with shales and containing some coal throughout.	1000 to 1200
					White River and Grand	Leaves and indistinct remains of plants. A few vertebrate remains on Plateau Creek.	Massive yellow sandstones below. Shales, gray and brown higher up. Yellow and pink sandstones near middle. White and yellow sandstones and shales near top. Coal near top.	1300
				Puerco marls.	Mesa Verde......	....	Variegated shales and marls. Pink, red, maroon, yellow, greenish, gray. Interstrata of sandstones and dolomites.	600 to 850
					Animas River ..	....	Variegated shales and marls. Same colors as above. Thin beds of sandstone throughout. Capped by heavy sandstone.	1000 to 1200
					Grand River....	....	Variegated shales and marls. The entire series is characteristically a "bad land" formation.	800

Synopsis of the geological formations found in Colorado—Continued.

			Locality.	Fossils.	Character of strata.	Thickness of strata in feet.
CENOZOIC.	POST-CRETACEOUS.	*Laramie Group.*	Mesa Verde		Yellow and brownish sandstones, mostly argillaceous. Sandy shales. Coal near base. Shales changing into marls.	800
			Trinidad region. Raton Hills.	*Spheria lapidea, Chondrites subsimplex, C. bulbosus, Delesseria fulva, D. lingulata, Halymenites striatus, H. major. Abietites dubius, Arundo Goepperti, Phragmites oeningensis, Sabal Campbelli, Flabellaria longirachis, Populus monodon, P. mutabilis, Ulmus irregularis, Ficus ulmifolia, Platanus Haydeni, Laurus pedata, Andromeda Grayana, Dombeiopis obtusa, Rhamnus obovatus, R. delctus, R. Fisheri, Juglans Smithsoniana, Carpolitus palmerum. Pteris erosa.*	Yellow sandstones and shales near base. Some white sandstone. Coal on top of the latter. Then follows a heavy series of gray and yellow sandstones and shales, with thin seams of coal near top.	2700
			Near Cañon City		Series of shales with interstrata of sandstones, sometimes massive. Coal at several horizons.	220
			Near Golden City	*Sclerotium rubellum, Delesseria fulva, Halymenites striatus, H. major, H. minor, Woodwardia latiloba, Pteris pennæformis, P. anceps, P. affinis P. erosa, P. subsimplex, Diplazium Muelleri, Aspidium Goldianum, Sphenopteris eocinica, S. membranacea, Hymenophyllum confusum, Selaginella Berthoudi, Abietites dubius, Phragmites œningensis, Carax berthoudi, Smilax grandifolia, Sabal Campbelli, S. Goldiana S. major, Flabellaria zinkeni, F. latania, F. fructifera Zingiberites undulatus, Populus attenuata, P. heliadum, Salix integra, Betula gracilis, Ulmus irregularis, Quercus angustiloba, Q. chlorophylla, Q. triangularis, Q. stramineus, Q. furcivervis, Q. Goldianus, Fagus peroniæ, Ficus tiliæfolia, F.*	Sandstones and clays near base. Alternating sandstones, clays, shales, and bed of coal. Higher up white and yellow sandstones, sometimes conglomeritic.	3200

Synopsis of the geological formations found in Colorado—Continued.

				Locality.	Fossils.	Character of strata.	Thickness of strata in feet.
CENOZOIC.	POST-CRETACEOUS.		*Laramie Group.*	Near Golden City—Continued.	*planicostata, F. asarifolia, F. zizyphoides, F. spectabilis, F. auriculata, F. truncata, Platanus Haydeni. P. rhomboidea, Artocarpedium olmediæ foluum, Benzoin antiquum, Cinnamomum Rossmaessleri, Viburnum Lakesii, Cornus Studeri, C. orbifera, Cissus lævigata, Nelumbium Lakesianum, Magnolia Lesleyana, Dombeiopsis trivialis, D. grandifolia, Sapindus candatus, Zizyphus distortus, Ceanotum fibrillosus, Berchensia parvifolia, Rhamnus obovatus, R. salicifolius, R. rectinerous, R. acuminatifolius, R. Goldianus, B. Cleburni, R. inæqualis, R. alaternoides, Juglans rugosa, J. Schimperi, J. rhamnoides, Carpolithes palmarum.*		
MESOZOIC.	CRETACEOUS.		*Fox Hills Group.*	Mesa Verde		Massive sandstones at base, followed by sandstones, shales, and marls with coal. Above these massive sandstones, then shales and clays with sandstones at top.	1900
				Animas River		Sandstones interbedded with some shales and coal near base. Heavy strata of yellow and gray shales. Sandstones near top.	1700
				White River		Sandstones, yellow and gray, below. Above them a series of sandstones and shales alternating. Near top massive sandstones.	1500
				Rio Nutria	*Inoceramus, Ostrea, Baculites.* Plants near top.	Yellow sandstones near base. Higher up yellow and gray arenaceous shales. Yellow and brownish sandstones near top.	1400
				Uncompahgre agency		Black shales at base. Yellow and light gray shales higher up, passing into arenaceous shales and sandstones near top.	1600
				O Be Joyful Creek		Sandstones changing into shales near base. Mostly sandstone, with thinner shale-strata higher up and near top.	850

Synopsis of the geological formations found in Colorado—Continued.

Era	Period	Group	Locality.	Fossils.	Character of strata.	Thickness of strata in feet.
MESOZOIC.	CRETACEOUS.	*Fox Hills Group.*	Gunnison River	*Inoceramus, Ostrea lugubris, Prionocyclas Wyomingensis, Scaphites Warrenana. I. problematicus.*	Yellow, shaly sandstones, changing higher up into yellow and gray shales. Farther up black shales, alternating with brown argillaceous sandstones. Shales near top.	690
			Bear Cañon	*Inoceramus*	Thin, shaly limestones near base. Higher up limestone and shales with gypsum. Partly arenaceous. Three hundred feet of dark gray, partly calcareous shales. Rusty yellow and brown sandstone on top.	485
			Little Thompson		(Section not complete.) Light gray, compact limestones near base. Blue-gray shady limestones higher up, followed by shaly, yellow limestones.	150
			Diminution of thickness from west to east is noticeable.			
		Colorado Group.	Rio San Juan	*Ostrea, Gryphœa*	Gray and yellow shales with brown sandstones toward middle. Shales argillaceous, arenaceous, and calcareous toward top.	1000
			White River		Dark gray shales. Sandstones, brown, argillaceous near base and top.	900
			Animas River	*Inoceramus, Ostrea*	Dark gray, almost black shales. Toward top, thin strata of yellow sandstones and brown shales with coal-beds.	800
			Junction of Rios Blanco and San Juan.	*Inoceramus*	Dark gray, fossiliferous shales at base. Yellow sandstone interbedded with thin strata of shale. Grayish-brown and yellowish shales. Yellow and white sandstones. This extraordinary widening is probably local.	2500
			Pagosa Springs	*Inoceramus*	Dark gray shales. Near the middle thin laminated sandstones. Sandstones with carbonaceous shales at top.	1100
			Canyon City	*Inoceramus, Ostrea*	Light yellow and gray shales. Calcareous near top, with white and yellow sandstones.	400
			Bear Cañon		Dark argillaceous shales, growing lighter toward the top.	120
			Little Thompson		Fine black shales near the base, followed by thin beds of crumbling sandstones. Higher up, black shales again. Thin, dark shales and slates, with some beds of limestone near top.	400
			A gradual thinning out of the strata can be observed as we proceed eastward.			

Synopsis of the geological formations found in Colorado—Continued.

				Locality.	Fossils.	Character of strata.	Thickness of strata in feet.
MESOZOIC.	CRETACEOUS.		*Dakota Group.*	Rio San Miguel	*Inoceramus, Gryphæa.*	White and light yellow massive sandstones near base. Higher up heavy beds of yellow sandstones. Thin sandstones and carbonaceous shales near top.	1000
				Uncompahgre Cañon		Yellow and white sandstones. Some shales near the middle with anthracitic coal.	
				Animas River	*Gryphæa*	Heavy white and yellow sandstones at base. Thinly bedded with shales higher up. White near top, with some coal.	900
				Rio Piedra	Indistinct plants near top.	Yellow and white sandstones. Partly quartzitic. Some shales near top.	1100
				Gunnison River	*Sassafras* like *S. mirabile. Scaphites.*	Yellow and pink sandstones near base. Series of shales and sandstones followed by heavy white and yellow sandstones near top.	900
				South Platte River	*Proteoïdes* like *P. acuta.*	Massive yellow sandstones below. Shales and shaly sandstones with carbonaceous matter near top.	385
				Grand River		Light green sandstones near base. Massive gray and white sandstones with shales near top.	200
				Bear Cañon	Indistinct plants near the middle.	Hard, white, yellow and grayish sandstones. Thinly bedded sandstones with shales near top.	240
				A decrease in thickness is very noticeable going from west to east.			
	JURA.		*Variegated Beds.*	Gunnison River		Gray sandstones, gray and greenish shales and marls near base. Dark blue limestones, shales and sandstones near top.	250
				Roaring Fork		Sandstones, shales, and marls near base, shales with some blue limestone near top.	440
				Eagle River		Gray, shaly sandstones, with limestones higher up. Shales, marls, and limestones near top.	960
				South Platte River		Red limestones near base. Arenaceous limestones and calcareous shales higher up.	150
				Pleasant Park		Pink and white limestones near base. Shales, sandstones, and limestones near top.	460
				Near Canyon City		Gray and greenish marls and shales, with interstrata of sandstones and limestones.	380
				Bear Cañon		Soft red sandstones at base. Alternating sandstones and limestones, with some shales near top.	870
				Ralston Creek		Red arenaceous shales and argillaceous sandstones near base. Variegated shales, with thin strata of limestones.	660

Synopsis of the geological formations found in Colorado—Continued.

			Locality.	Fossils.	Character of strata.	Thickness of strata in feet.
MESOZOIC.	JURA.	*Variegated Beds.*	Big Thompson	Dr. Hayden, Report 1869, p. 119, found on Box Elder Creek, north of Big Thompson, a species of *Ostrea* and *Pentacrinus asteriscus.*	Reddish-grey sandstone below, thin beds of limestone and variegated clays higher up.	260
			Saint Vrain's Creek		Red shaly sandstones near base, alternating beds of soft sandstones and shales, with limestones near top.	450
			Average thickness of strata			490
	TRIAS.	*Red Beds.*	Unaweep Cañon		Massive red sandstones and shales.	600
			Rio Dolores		Red sandstones and shales.	1000
			Eagle River		Red, massive sandstones, with some white near base. Lighter colored and shaly toward top.	1000
			Near Greenhorn Mts		Heavy sandstones, becoming shaly toward the middle, changing with white sandstones near top.	1200
			Near Canyon City		Massive red sandstones with white and red sandstones and shales near top.	1200
			South Platte River		White and red mottled sandstones, red and white, with red bands near top.	2100
			Pleasant Park		White and red sandstones near base. Massive red near top.	1500
			Glen Eyrie		Massive red sandstones, pink and white higher up.	1100
			Garden of the Gods		Red and white sandstones, with brilliant red shales.	1500 to 2000
			South of Golden		Red massive sandstones, with shales. White and pink near top.	1600
			Near Golden		Here the group has shrunk considerably. Mainly red sandstone.	400
			Little Thompson		Soft, red sandstones below. Above them 250 to 300 feet, shaly sandstones, capped by about 250 feet massive red sandstones.	750
			Average thickness of strata			1200
PALÆOZOIC.	PERMIAN.	*Permian.*	Eagle River	*Calamites Suckovii, Stigmaria fucoïdes, Calamites gigas.*	Sandstones and shales with limestones toward the top.	800
		Permo-carboniferous.	Eagle River	Indistinct remains of plants.	Extensive series of sandstones, shales, and limestones.	1500

Synopsis of the geological formations found in Colorado—Continued.

				Locality.	Fossils.	Character of strata.	Thickness of strata in feet.
PALÆOZOIC.	CARBONIFEROUS.	UPPER CARBONIFEROUS.		Head of Salt Creek		Pink and red sandstones and shales with gypsum.	1700
				Dolores region		Pink, conglomeritic sandstones, and red shales.	1000
				Animas River	*Athyris subtilita, Productus.*	Red sandstones with interstrata of shales.	1400
				Mineral Creek		Red sandstones, partly conglomeritic.	1800
				Park range		Red, pink, and maroon sandstones with thin beds of limestone.	2000 to 2500
				Veta Pass	*Sigillaria, Calamites, Productus, Spirifer, Athyris.*	Red sandstones and shales with bands of limestone.	2200
			Arkansas Sandstone.	Sangre de Cristo Range.	*Crinoïds, Productus, Spirifer, Orthis.*	Red sandstones with interstrata of shales and bands of limestone.	2400
				Arkansas River	*Crinoïds, corals.*	Massive red sandstones with limestones.	4000
				Average thickness of strata			2000
		MIDDLE CARBONIFEROUS.		Head of Salt Creek		Sandstones, shales, and probably limestones.	3500
				Animas near Cascade Creek.	Indistinct plants	Yellow and gray sandstones and shales.	1200
				Animas near Junction Creek.	*Productus semistriatus, Athyris subtilita, Spirifer.*	Occurring in limestones belonging to top of sandstone and shale series.	1300
				Eagle River	*Avicula, Aviculopecten, Pleurophorus.*	Variegated sandstones and shales, with limestones near base.	2500
				Elk Mountains	*Productus, Athyris, Rhynchonella, Hemipronites, Retzia.*	Yellow, gray, and reddish sandstones and shales with limestones.	1300 to 2000
				Park Range	*Productus, Athyris, Spirifer.*	Greenish and gray sandstones and shales. Limestones.	2000
				Grand River		Yellow and gray sandstones and shales.	640
				Badger Creek	*Orthis, Productus, Orthoceras.*	Gray and brown sandstones and shales. Limestones.	800
				Average thickness of strata			1700
		LOWER CARBONIFEROUS.	*Sub-carboniferous.*	Head of Salt Creek	*Productus, Crinoïds, Corals.*	Shaly sandstones and blue limestones.	300
				Near Animas River	*Productus, Spirifer, Crinoïds.*	Massive blue limestones	400
				Eagle River		Massive limestones	500
				Elk Mountains		Limestones and calcareous shales.	600
				Park Range		Blue limestones are predominating. Arenaceous shales.	300 to 400
				Pleasant Park	*Terebratula, Spiriferina.*	Cherty blue and gray limestones.	114
				Average thickness of strata			380

Synopsis of the geological formations found in Colorado—Continued.

				Locality.	Fossils.	Character of strata.	Thickness of strata in feet.
PALÆOZOIC.	DEVONIAN.			Lime Creek	*Rhynchonella, Spirifer, Crinoïds.*	Massive blue limestones	1200 to 1500
				South of Mount Oso	*Productus subaculeatus, Orthoceras, Athyris, Bellerophon, Euomphalus, Rhynchonella Endlichi.*	Massive blue limestones, with sandstones and shales near top.	400
	SILURIAN.	TRENTON PERIOD. (?)		Eagle River	....	Light blue limestones, mostly magnesian.	220
		PRIMORDIAL PERIOD.	*Calciferous Group. (Quebec.)*	Eagle River	....	Quartzites, sandstones, and blue limestones.	200
				Four-mile Creek	*Orthis desmopleura, Euomphalus.*	Blue and gray limestones, partly magnesian.	200
				North of Mount Ouray	....	Light gray and blue limestones.	200
				North of Arkansas River.	*Heterocrinus, Orthoceras.*	Dark gray quartzitic limestones.	150
				Trout Creek	*Lingulepis, Obolus, Orthis desmopleura, Euomphalus.*	Red calcareous sandstones and pink limestones.	100 to 150
				Along the border of Front Range, between Colorado Springs and cañon.	....	Hard gray limestones, quartzitic in part.	180
				Glen Eyrie	*Bucanella nana*	Red shaly limestone	70
				Williams' Cañon	*Ophileta complanata.*	Reddish arenaceous limestones.	......
				Average thickness of strata			160
			Potsdam Group.	Lime Creek	....	White sandstone and quartzite.	250
				Eagle River	....	White quartzites	300 to 400
				Four-mile Creek	....	Red and pink sandstones and quartzites.	160
				Trout Creek	....	Yellow and pink sandstones	80
				North of Mount Ouray	....	White and pink quartzites	200
				Near Canyon City	....	Variegated micaceous and calcareous sandstones	......
				Glen Eyrie	....	Red sandstones and quartzites.	40
				Average thickness of strata			180

THICKNESSES OF FORMATIONS AT CERTAIN LOCALITIES.

Locality.	Groups.	Thickness.
	Tertiary.	
White River and Grand	Green River Wahsatch	5300
Animas River	Wahsatch	2200 to 2600
	Post-Cretaceous.	
Trinidad		2700
Golden		3200
	Cretaceous.	
Mesa Verde	Fox Hills Colorado Dakota	3500 to 4800
Animas River	Fox Hills Colorado Dakota	3400
White River	Fox Hills Colorado Dakota	3600
Region of Rio Piedra	Fox Hills Colorado Dakota	3600 to 5000
Bear Cañon	Fox Hills Colorado Dakota	750
	Jura.	
Eagle River		960
Pleasant Park		460
Bear Cañon		870
Saint Vrain's Creek		450
	Trias.	
Unaweep Cañon		600
Eagle River		1000
Canyon City		1200
Pleasant Park		1500
Glen Eyrie		1100
Little Thompson		750
	Permian.	
Eagle River	Permian Permo-carboniferous	2300
	Carboniferous.	
Head of Salt Creek	Upper Carboniferous Middle Carboniferous Lower Carboniferous	5500
Animas Region	Upper Carboniferous Middle Carboniferous Lower Carboniferous	3100
Park Range	Upper Carboniferous Middle Carboniferous Lower Carboniferous	4300 to 4900
Elk Mountains	Upper Carboniferous Middle Carboniferous Lower Carboniferous	4500 to 5000
	Devonian.	
Lime Creek		1200 to 1500
	Silurian.	
Eagle River	Trenton (?) Calciferous Potsdam	770
Four Mile Creek	Calciferous Potsdam	360
North of Mount Ouray	Calciferous Potsdam	400
Glen Eyrie	Calciferous Potsdam	110

Adding the thickness of all the sedimentary formations occurring in Colorado, we arrive at the maximum result, giving a thickness of 24,500 feet.

MINERALOGICAL REPORT OF F. M. ENDLICH, S. N. D.

LETTER OF TRANSMITTAL.

WASHINGTON, D. C., *January* 2, 1878.

SIR: I have the honor herewith to transmit the "Catalogue of Minerals found in Colorado." It has been made as complete as possible, up to date.

A plan differing from that previously followed has been adopted. So far as practicable, analyses of Colorado minerals have been given. They will aid examination and show the interest taken by specialists in the minerals from this State. All available material has been utilized in the preparation of the catalogue. A systematic enumeration of the Colorado mineral species and references to the publications thereon have been added.

I desire here to thank those gentlemen to whom I am indebted for verbal and written information.

Hoping that the subjoined pages may meet your requirements,

I am, very respectfully, your obedient servant,

FREDERIC M. ENDLICH.

Dr. F. V. HAYDEN,
Geologist-in-charge United States
Geological and Geographical Survey of the Territories.

CATALOGUE OF MINERALS FOUND IN COLORADO.

By F. M. Endlich, S. N. D.

The continuous development of mineral resources of Colorado is productive of a more complete knowledge, not only of their distribution, but of their specific character. In 1873, I published my first catalogue of minerals of that Territory. An enlarged list was printed in the United States Geological Report for 1875. Now, the survey of Colorado is completed, many additions of species new to the State and of new localities for known ones have been obtained. With a view, therefore, of presenting, as complete as possible, a catalogue of Colorado minerals I have undertaken its preparation a third time. In so doing, I have availed myself of all accessible material. Publications and private communications by the following gentlemen have furnished very material aid in the completion of the work: Dr. F. V. Hayden, United States Geologist; Capt. E. L. Berthoud, Golden, Colo.; Prof. J. D. Dana, New Haven, Conn.; Prof. P. Frazer, E. M., Philadelphia; Prof. F. A. Genth, University of Pennsylvania, Philadelphia; E. Goldsmith, Philadelphia; J. D. Hague, E. M., Survey of the Fortieth Parallel; Prof. N. P. Hill, Black Hawk, Colo.; W. H. Holmes, United States Geological Survey; Dr. G. A. Koenig, Philadelphia; Dr. O. Loew, Survey West of the One Hundredth Meridian; Prof. J. E. Mallett, jr., Canyon City, Colo.; W. McCree, E. M., Del Norte, Colo.; Dr. A. C. Peale, United States Geological Survey; Mr. Richard Pearce, Black Hawk, Colo.; Mr. Peters, E. M., Fairplay, Colo.; R. J. Raymond, United States Mining and Mineral Commissioner; Prof. J. F. L. Schirmer, Denver, Colo.; A. von Schulz, E. M., Black Hawk, Colo.; Prof. B. Silliman, New Haven, Conn.; J. Alden Smith, State Geologist, Boulder City, Col.

An arrangement has been followed differing somewhat from that adopted in previous catalogues. So far as was possible, only well-accepted mineral species have been enumerated, without according specific positions to the varieties. The most popular names for certain species have been inserted, and references have been made leading to the name accepted by mineralogists. It is intended that every available analysis of Colorado minerals should be given. Necessarily many that have been made and might prove valuable cannot be obtained. So far as possible this intention has been carried out. Analyses of ores or metal-assays are not given, as they would be of no mineralogical value, however interesting to the miner and smelter.

A systematic enumeration of the species occurring has been given at the end of the catalogue. It is arranged in accordance with Dana's system of mineralogy. In addition thereto, reference is made to publications bearing upon the mineralogy of the State of Colorado.

Undoubtedly the most interesting mineral occurrence in Colorado is that of the tellurides. Gold, silver, lead, iron, mercury, and oxygen are combined with the tellurium, forming compounds that have either been considered heretofore as among the rarest, or were totally unknown to science. At no place have tellurides occurred in such large quantities and in such admirable form. As ores they are greatly sought after on account of the high percentages of gold and silver they contain. Another

rare occurrence is that of the pitchblende. It is to be regretted that the mine is not worked at present, and has not been for several years. Thus much that might be learned as to its distribution in the vein is lost.

Among those minerals classed as "ores," the argentiferous species are prominent in Colorado. Compounds of sulphur, antimony, tellurium, bismuth, arsenic, and other metals and metalloids with silver, are found in varying ratio. Galenite may be regarded as invariably silver-bearing. I have made more than a hundred assays of western galenites and have never failed to find the precious metal. It remains to be said that the percentage is highly variable, and that, as a rule, it is small unless argentite be present in the mineral. This is not unfrequently the case. It may be noticed that many very coarse-grained galenites show, upon breaking, dark gray, or black, dull, cleavage-planes. This is, in many instances, produced by a very thin coating of argentite.

It is not to be supposed that the number of minerals occurring at any particular locality could be fully ascertained by members of the survey while examining the region. During the regular field-work only such mineral localities will be obtained that happen to be found more or less accidentally. It may be hoped, therefore, that in future years more knowledge will be gained regarding the non-metalliferous minerals. Of these the enumeration at the present time is rather meagre.

Thus far but comparatively few epigene minerals have been found in Colorado, considering the large number of mines worked. With increasing depth of the mines, and time, no doubt the mineralogist will eventually be rewarded, and will find many a secondary mineral-product that now he looks for in vain. Upon undisturbed dumps a few such species have been collected.

Should further discoveries, or more complete examination of the mineral regions already known warrant it, I propose to prepare another edition of the catalogue whenever such preparation may seem advisable.

ACTINOLITE.—In radiated form, of light-green and bluish green color, on Mount Ouray; on Buffalo and Sopris Peaks; crystallized at Bergen's Ranch, Jefferson County; on Boulder Peak.

AGATE.—*See* QUARTZ.

ALABANDITE.—At Quartzville.

ALABASTER.—*See* GYPSUM.

ALBITE.—Quartz Hill, Central City; Gold Hill, Boulder County.

ALMANDITE.—*See* GARNET.

ALLOPHANITE.—Franklin Mine, in Gilson Gulch; Fowler and Wells's Branch, Sugar-Loaf district.

ALTAITE.—Red Cloud and Cold Spring Mines, Gold Hill. It occurs in various mines of the Sunshine district; minute crystals were obtained from the Red Cloud. Analyses, published by Genth,* show the following result. The specimen was from the Red Cloud Mine:

	(1) Per cent.	(2) Per cent.
Quartz	0.19	0.32
Gold	0.19	0.16
Silver	0.62	0.76
Copper	0.06	0.06
Lead	60.22	60.53
Zinc	0.15	0.04
Iron	0.48	0.33
Tellurium	37.99	37.51
	99.90	99.74

* Proc. Am. Phil. Soc., Philadelphia. Vol. XIV., p. 226, 1876.

ALUM.—Mount Vernon.

ALUMINITE.—Mount Vernon.

AMALGAMITE.—Occurring in connection with coloradoite in the Keystone Mine, Boulder County.

AMBER.—(One specimen found near the head of Cherry Creek. This may, however, be one of the numerous resins occurring in the lignitic coal. They resemble amber, but differ in composition. See WHEELERITE.)

AMETHYST.—*See* QUARTZ.

AMIANTHITE.—North Boulder Creek.

AMPHIBOLITE.—Occurs at numerous localities in the dikes traversing granite. Small acicular crystals can be obtained from the porphyritic and sanidinitic trachytes. Good crystals are rare. Found on Buffalo Peaks; Montgomery; Head of Ohio Creek in volcanic breccia; on the Gunnison in trachytes.

ANALCITE.—In minute crystals in basalt, near Uncompahgre Peak.

ANDESITE.—Minute crystals in the trachytes near Black Mountain.

ANGLESITE.—Freeland Mine, on Trail Creek. In crystals at the Horseshoe lead mine, in South Park. Clifton lode, at Central City. Prospector lode, in Arastra Gulch, near Silverton.

ANHYDRITE.—On Elk Creek. Crystallized at the salt-works in South Park.

ANTHOPHYLLITE.—North Boulder Creek.

ANTHRACITE.—Anthracite Creek; "O Be Joyful" Creek; in the Elk Mountains; in Uncompahgre Cañon. This anthracitic coal is of Lower and Upper Cretaceous age. Partly its greater age, partly other causes, have given to it the anthracitic character. Nearly all of it was originally simply bituminous coal. Dr. Peale, with reference thereto, says:* "The eruption of the trachyte found near the coal first mentioned, probably so heated it as to deprive it of the bituminous matter." An analysis made by Dr. Peale of coal from Anthracite Creek furnished the following result:

Water	1.60
Fixed carbon	88.20
Volatile combustible matter	3.40
Ash	6.80

An average taken from seven analyses of Elk Mountain anthracite furnishes:

Water	2.757
Fixed carbon	77.360
Volatile combustible matter	13.620
Ash	6.291
Specific gravity	1.740

ANTIMONY.—Gold Hill; found there in minute crystals.

ANTRIMOLITE.—*See* MESOLITE.

APATITE.—At Fairplay.

APOPHYLLITE.—Hunt's Peak. Reported from some of the basalts near San Luis Valley.

ARAGONITE.—Occurring in the form usually termed *flos ferri*, very beautifully in Marshal's Tunnel, Georgetown, Golden. Table Mountain. In the trachytes near Del Norte; on the Rio Grande, above Fir Creek; at Idaho Springs.

* Rep. U. S. Geol. Surv., 1874, p. 176.

ARFVEDSONITE.—Occurs in quartz in El Paso County. An analysis furnished Dr. G. A. Koenig the following result:*

	Per cent.
$Si\ O_2$	49.83
$Ti\ O_2$	1.43
$Zr\ O_2$	0.75
$Al_2\ O_3$	trace
$Fe_2\ O_3$	15.88
$Fe\ O$	17.95
$Mn\ O$	1.75
$Na_2\ O$ } $Li\ O$ }	8.33
$K_2\ O$	1.44
$Mag\ O$	0.41
Ignition	0.21
	97.97

ARGENTITE.—Colorado Central Mine, Terrible, and other mines near Georgetown; in the No-Name, Caribou, and others at Caribou; in some of the silver lodes near Nevada; in the Senator lode of the Hardscrabble district; in many of the lodes of the San Juan mining region associated with fahlerz and pyrargyrite. At the Silver Star, Moose, and other mines near Fairplay. Usually it is found in small, irregular particles or seams, rarely crystallized. Decomposition results in the formation of native silver.

ARSENOPYRITE.—Crystallized and massive in the Bobtail and Gunnell mines. Intimately associated with pyrite and chalcopyrite there. Generally auriferous. Together with silver and copper at the Park lode, Bergens ranch. Occurs also in the Priest Mine near Fairplay. With franklinite on Rio Dolores, Nevada district, Gilpin County.

ASBESTOS.—Occurs in small quantities, partly radiated, near Caribou.

ASPHALT.—Found in the White River region. It occurs in veins, is very compact and brittle. Occurs in springs near the summit of the Book Cliffs; Canyon City. (Loew.) Several of the petroleoid products of Colorado have been termed asphalt.

ASTROPHYLLITE.—Occurs in quartz on Cheyenne Mountain. Imbedded in quartz in El Paso County. An analysis furnished Dr. G. A. Koenig the following result:*

	Per cent.
$Si\ O_2$	34.68
$Ti\ O_2$	13.58
$Zr\ O_2$	2.56
$Fe_2\ O_3$	6.56
$Al_2\ O_3$	0.70
$Fe\ O$	26.10
$Mn\ O$	3.48
$K_2\ O$	5.01
$Na_2\ O$	2.51
$Mag\ O$	0.30
$Cu\ O$	0.42
$Ta\ O_2$	0.80
$H_2\ O$	3.54
	99.91

ATACAMITE.—On Kendall Mountain in some of the argentiferous lodes near Howardsville.

AVENTURINE FELDSPAR.—*See* ORTHOCLASE.

AVENTURINE QUARTZ.—*See* QUARTZ.

* Proc. Ac. Nat. Sci. Phil., Part i, 1877, p. 9.

AZURITE.—In the No-Name, together with malachite, the result of decomposition of fahlerz, Caribou; in the Rosita mines in Hardscrabble district; in the mines around Fairplay and Idaho; on Trail Creek; Crater Mountain; in the mines of the Elk Mountain district, Malachite lode, Bear Creek, Gendhemas lode, Tucker's Gulch. Generally the azurite is regarded as "blossom-rock" by the miners. If resulting from the decomposition of fahlerz it usually indicates silver-bearing ore. No crystals of any size were observed, the largest scarcely measuring 0.5 millimeter. Small, very brilliant crystals were found on Kendall Mountain, near Howardsville.

BARITE.—In clear, yellow, tabular crystals in the Tenth Legion Mine, at Empire; colorless crystals in the Terrible, at Georgetown; near Canyon City, transparent crystals are found in the arenaceous shales of that region. Crystals occur in the limestones near Fairplay; on the Apishpa River, crystals with fine terminations are found. Barite occurs also in Gilson Gulch, Georgetown; Montezuma; white, red, and brown in Clear Creek Cañon; on station 17 of 1873, and on station 46 of 1873. At the Rosita mines.

BASANITE.—*See* QUARTZ.

BERYL.—On Bear Creek, Tiffany's Ranch; Stone Dam, Jefferson County.

BIOTITE.—On Buffalo Peak and station 64 of 1873. Several of the trachytes, more particularly the porphyritic, contain small crystals of biotite. It is also found in some of the basalt. When decomposed it becomes splendent brown, otherwise it is very dark green, brown, or black.

BISMUTH.—French Gulch.

BISMUTHINITE.—In the Las Animas Mine, pseudomorphous. Dr. O. Loew* mentions copper and iron as occurring in the bismuthinite of the Ward district. Occurs in the Pittsburgh Mine, Clear Creek County.

BISMUTITE.—From the Las Animas Mine, incrusting the preceding mineral.

BITUMINOUS COAL.—*See* COAL.

BORNITE.—Found on Rio Dolores; San Juan region; at Copperville, near Cañon City.

BOURNONITE.—Terrible Mine, near Georgetown, in small crystals.

BRUCITE.—On James Creek.

CALAMINE.—Park County.

CALAVERITE.—Associated with other tellurides in the Red Cloud. Good crystals have been obtained from Sunshine district. Found in the Keystone and Mountain Lion Mine, Boulder County. Genth publishes an analysis of calaverite,† and obtains the following result:

	Per cent.
Au	38.75
Ag	3.05
Te	57.32
V_2O_3	0.05
FeO	0.30
Al_2O_3 MgO, &c	0.55
	100.00

CALCITE.—In small crystals, scalenohedra, at the Monte Cristo Mine, Central; Mount Vernon; Bergen's ranch; rhombohedral crystals on Cheyenne Mountain; in the limestones of South Park; in the carboniferous limestones near the Arkansas River, lining cavities; sca-

* Explorations and Surveys West of the 100th Meridian, vol. iii, p. 636.
† Zeitschr. für Kryst. und Min., P. Groth, vol. ii, No. 1, p. 6, 1877.

lenohedra in the Elk Mountain district; fibrous in Trout Creek Park; on Frying-pan Creek. Brown, rose-colored, yellow, and white on Table Mountain at Golden; scalenohedra and combinations of rhombohedra in quartz geodes near Ouray.

Marble.—Marble occurs at several localities in Colorado. North of the Gunnison near Taylor River Park is perhaps the most extensive deposit.

CALEDONITE.—Freeland Mine, Trail Creek.

CAOLINITE.—Camp near Mount Princeton. The white, chalk-like bluffs on Chalk Creek near Mount Princeton owe their appearance to the presence of caolinite. There it is the product of decomposed oligoclase.

CARNALLITE.—Salt-works, South Park.

CARNELIAN.—*See* QUARTZ.

CERARGYRITE.—Gilpin County lode, Black Hawk. Small compact quantities in the Wade Hampton Mine, Argentine, Caribou. Small specimens were obtained from the Red Cloud Mine, Gold Hill. At the Rosita mines. Reported from Upper Animas region.

CERUSSITE.—J. P. Whitney Mine; in very small crystals, Central; No-Name, Caribou; Caribou mine; Silver Hills mines and Rosita mines, in the Hardscrabble district. Freeland Mine, Trail Creek. In the Horseshoe Mine it occurs earthy, and is found throughout the mines of Elk Mountain district. Cañon City. Found also in the Prospector lode, Arastra Gulch, near Silverton.

CHABAZITE.—Golden, Colo., Table Mountain. In basaltic geodes near Uncompahgre Peak.

CHALCANTHITE.—On Clear Creek, below Black Hawk, in a deposit, and on several dumps near Central, in this case an epigene species of chalcopyrite.

CHALCEDONY.—*See* QUARTZ.

CHALCOCITE.—Bergen district, near Idaho City. Liberty lode, Bear Creek, Cañon City. At the Rosita mines.

CHALCOPYRITE.—Malachite and Pocahontas lodes, Bear Creek. Auriferous in the Bobtail, Winnebago, Dallas, Gunnell, Running, Kansas, Alps, California, and other mines at or near Central; mostly it occurs compact, intimately associated with pyrite. It is found in every paying gold mine of Gilpin County, and the miners seem to think a great portion of the "pay" dependent upon its presence. It also occurs in the Terrible, Pelican, Cold Stream, and other mines of Georgetown, as well as in those of Caribou and Hardscrabble. In the Trinidad gold-mining district, near Culebra Peak; in the gold and silver mines of Fair Play and the Elk Mountain district; on the Dolores River near Mount Wilson.

CHLOANTHITE.—Arkansas River.

CHLORITE.—On Mount Princeton; on Trail Creek; on Sopris Peak. At some localities chlorite replaces the mica either in granite or schists. Mostly, the mineral occurs only in very thin flakes without crystalline faces.

CHLOROPHANITE.—Bergen district.

CHROMITE.—Massive, Silver Hills and Fair Play.

CHRYSOCOLLA.—Champion lode, Trail Creek, Cañon City; Allen's copper mine, head of San Luis Valley.

CHRYSOLITE.—So far as can be determined, the chrysolite associated with the Fort Defiance garnets extends into Colorado. (Compare Lieutenant Wheeler's Annual Report 1875, Vol. iii., p. 105.)

CHRYSOPRASE.—*See* QUARTZ.

COAL.—(Compare ANTHRACITE.) Coal occurs and is worked at a number of localities in Colorado. Two horizons, mainly of coal-beds, can be distinguished—the Cretaceous and the Post-cretaceous. With the exception of the anthracoïd coal of the Elk Mountains and adjacent regions, the Colorado coal is mostly a *coking* or *binding bituminous* coal. Some of the banks, however, furnish coal that cannot be utilized for coking purposes. All of this is the coal to which the term "lignite" has been applied. Cretaceous coal is found on the divide between the Uncompahgre and Cebolla, Elk Mountains, on the Lower Animas, the Florida, and on the La Plata. Post-cretaceous coal occurs along the Front Range: near Boulder, at Golden, at Colorado Springs, at Cañon, near Pueblo and Trinidad, and westward from that town. On Trout Creek Pass. In the region of the White River a number of coal veins are found, belonging to this group.

Four analyses of coal from the Animas region furnished the following average result:

Water	3.730
Fixed carbon	61.126
Volatile combustible matter	30.677
Ash	4.472
Specific gravity	1.346

Two analyses of coal from Boulder furnished the following average result:

Water	13.305
Fixed carbon	50.340
Volatile combustible matter	32.950
Ash	3.405
Specific gravity	1.270

Eleven analyses of coal from Golden gave the following average result:

Water	12.165
Fixed carbon	51.989
Volatile combustible matter	31.776
Ash	3.900
Specific gravity	1.341

Four analyses of coal from Colorado Springs presented the following average result:

Water	9.205
Mixed carbon	48.305
Volatile combustible matter	35.357
Ash	7.132
Specific gravity	1.325

Three analyses of coal from Canyon City furnished the following average result:

Water	5.090
Fixed carbon	56.053
Volatile combustible matter	35.226
Ash	3.630
Specific gravity	1.285

Five analyses of coal from Trinidad gave the following average result:

Water	0.792
Fixed carbon	55.768
Volatile combustible matter	32.488
Ash	11.133
Specific gravity	1.363

A total average prepared from thirty-four analyses of Colorado bituminous coal will furnish an idea as to its position in mineralogical classification.

Water	6.436
Fixed carbons	52.617
Volatile combustible matter	34.096
Ash	6.835
Specific gravity	1.325

COLORADOITE.—Occurs in Boulder County, in the Keystone Mine; in the Smuggler Mine, Ballerat district, Professor Genth furnishes several analyses.* 1, Keystone Mine; 2 and 3, Smuggler Mine.

	(1) Per cent.
Hg	52.28
Te	42.95
Al_2O_3 Fe_2O_3	2.44
V_2O_3	0.70
MgO	0.11
CaO	0.84
	99.32

	(2) Per cent.	(3) Per cent.
Quartz	2.90	3.05
Au	3.46	7.67
Ag	2.42	7.18
Hg	55.80	48.74
Cu	trace.	0.16
Zn	trace.	0.50
Fe	1.35	0.92
Te	36.24	34.49
	99.27	99.66

COLUMBITE.—Found occurring in prismatic needles piercing the Zirkon of Pike's Peak.

COPPER.—Native; arborescent in the Gregory lode. Ward district, Boulder County; Bergen's ranch. Arborescent on Jones's Mountain; in almond-shaped nuggets in placiers of Rio San Miguel.

COPPERASITE.—*See* JAROSITE.

COVELLITE.—Mosquito, Central City, Cañon City. (Loew.)

CUPRITE.—In crystals, from Sacramento Gulch and from the Sweet Home Mine, Malachite lode, Bear Creek, Gendhemas lode, Tucker's Gulch; massive on the Rio Dolores.

DOLOMITE.—From the Four-Mile Creek. Occurs as rock in a number of the formations of the State. Very rarely crystalized. Small geodes in Middle Cretaceous shales are sometimes lined with dolorite crystals.

DYSCRASITE.—Reported from the head of the Uncompahgre.

EMBOLITE.—Peru district; Snake River; Gold Hill.

ENARGITE.—Near Black Hawk. Found in the Powers Mine, Russell district, Gilpin County.

EPIDOTE.—Crystals associated with garnet on Gunnell Hill, Central. Throughout the metamorphics of the Front Range in minute crystals; crystals in the Sangre de Cristo Range; a large number of the hornblendic dikes contain massive epidote together with quartz. On the summit of Mount Bross; Lake Creek Cañon; Elk Mountain Range; on Trail Creek.

FAHLERZ.—Terrible, Colorado Central, Pelican, and other mines of Georgetown; No-Name, Caribou, and others at Caribou; Mount Princeton. Argentiferous, mostly antimonial, sometimes arsenical in the silver mines of the San Juan region. Crystals are very rare.

FELDSPAR.—*See* ANDESITE, LABRADORITE, OLIGOCLASE, ORTHOCLASE, and SANIDITE.

FIRE CLAY.—Golden, Ralston, Boulder, &c. Good fire-clay is obtained from the Animas coal-bearing beds.

FLOAT-STONE.—*See* PUMICE.

FLOS FERRI.—*See* ARAGONITE.

FLUORITE.—Terrible mine, Georgetown, in light-green cubes; in small crystals and massive, of violet color, on Mount McClellan and Gray's

(*Zeitschr. für Kryst. und Min. P. Groth, vol. II, No. 1, 1877.)

Peak. On Bear Creek; massive, pink and violet in the Sweet Home Home Mine, Clear Creek, and James Creek. Massive on Kendall Mountain, Howardsville.

FRANKLINITE.—Occurs in Mispickel (arsenopyrite), on Rio Dolores.

FREIESLEBENITE.—At the head of Cement Creek, near Baker's Park.

GALENITE.—In narrow seams, fine-grained in the Winnebago lode; feathery in the Dallas Mine; coarse-grained in the J. P. Whitney, Running, Monte Cristo, Forks, and other mines of Gilpin County. In the Colorado Central, Equator, Star, Pelican, Terrible, and others near Georgetown, it occurs in very large quantities. At the Cold Stream very fine crystals are found, combinations of cube and octahedron, rarely rhombic dodecahedron. The International, on Mount McClellan, at an elevation of 12,800 feet, has a heavy vein of galenite. The No-Name, Fourth of July, Caribou, and others in Boulder County cootain the mineral. Silver Hill mines (fine-grained) and the Rosita mines in Hardscrabble district. Hamilton, the mines around Fair Play show crystals; the mines of Elk Mountain district, the head of Iowa and Empire Gulch, contain galenite. In small, scattering quantities it is found almost throughout the State. Bear Creek, Grey Gulch. The Highland Mary, the mines of Cunningham and Arastra Gulches, on the forks of the Animas, in the Sneffels and Uncompahgre districts. Throughout the San Juan mines galenite is one of the principal ores. Invariably it is argentiferous, although the quantity of silver it contains changes greatly.

GARNET.—Crystallized in rhombic dodecahedra and sometimes icositetrahedra, associated with epidote on Gunnell Hill, Central. This occurrence (*spessartite*) closely resembles the garnets from Auerbach, in Germany. Occurs frequently in micaceous schists, Ouray group, northern end of Sangre de Cristo Range. On Trail Creek, Bergen, &c. Montgomery, Bear Creek, Tucker's Gulch. Near the southwest corner of Colorado, found in drift (*almandite*).

GLAUBER SALT.—Bear Creek, Smoky Creek. At a number of hot springs in Colorado.

GLOCKERITE.—Central City, Idaho Springs.

GOETHITE.—Occurs with hematite on Topaz Buttes.

GOLD.—Native gold in very small and in distinct crystals in the Bobtail, Gunnell, Kansas, and on Quartz Hill, near Central. In the gold gulches of Gilpin County. Many of these are worked out, others still yield nuggets and fine-gold. On Clear Creek. Tarryall Creek; Placer-diggings, near Fairplay, in imperfect crystals and laminæ. In Washington and California Gulches; in the placers of Union Park, and many other localities. In the Elk Mountains. Placers on San Miguel, on the Mancos and La Plata. Near Parrott City; in the Little Giant Mine, near Silverton, associated with ripidolite. Occurring as the result of decomposition of the tellurids in the Red Cloud, Cold Spring, and other lodes near Gold Hill. In the Ward and Sugar Loaf districts. In the American, Grand View, Silver Dale, and other mines in the Sunshine district. Impregnated in volcanic rock in the Summit district. It is very finely distributed there, and contained in pyrite. Upon the decomposition of pyrite, gold becomes free. In the Little Annie it was first discovered in this district. At Oro City, in rhyolite. In some of the South Park mines, in Potsdam sandstone. At the Nevada lode, in azurite. Very fine although small crystals have been lately obtained from the Gunnell, near Central. They are bright, on black sphalerite, and show combinations of cube, octahedron, and rhombic dodecahedron. Mixtures of gold and silver are found as the result of decomposition of tellurids containing both metals.

GOSLARITE.—On the dumps of the Wood lode, Leavenworth Gulch, near Central.

GRAPHIC GRANITE.—*See* PEGMATITE.

GRAPHITE.—Trinidad Mine, Las Animas County. Brad lode, San Juan district.

GREENOCKITE.—On sphalerite of the Dallas Mine, Black Hawk, Running Lode, Quartz Hill, Nevada. In mine of galena, on South Boulder.

GYPSUM.—Occurs at numerous localities.

Gypsum.—Compact in the Triassic and Cretaceous, sometimes Carboniferous formations.

Selenite.—Good crystals are rare. This form is more frequently found than the compact. Occurs in the Upper Carboniferous beds of Western and the Tertiary beds of Southern Colorado. In the Jurassic formation along the Front Range. On Eagle River, along the Lower White and Grand. Table Mountain, Golden.

Alabaster.—Occurs at Mount Vernon.

HALITE.—Salt-works of South Park, along some parts of the Platte River, in springs. Found at salt-licks in various parts of the Territory. Cañon City, Sinbad's Valley, Greenhorn Mountains.

HEMATITE.—

Specular.—Rhombs on quartz crystals, Topaz Buttes; Procer Hill, near Central; Phillip's Mine, Silver Hills; in the mines of Elk Mountain district, Bear Creek, Jefferson County, Unaweep Cañon. Fine crystals, iridescent, San Juan.

Micaceous.—Caribou, Ralston Creek, Unaweep Cañon, Sopris Peak. single crystals on quartz and some inclosed in amethyst at the Little Giant mines, near Silverton.

Fibrous.—Phillips Mine, Silver Hills.

HENRYITE.—Found first at the Red Cloud and Cold Spring mines; later in all the telluride mines of Gold Hill, Ward, Sugar Loaf, and Sunshine districts. Fine crystals are very rare; minute ones are found, but rather imperfect. An analysis* furnished the following result:

Pb	53.19
Fe	5.05
Ag	0.31
Au	trace.
Te	41.45
Specific gravity	8.5253

(Compare altaite.)

HESSITE.—Gold Hill, Boulder County; a telluride that may be hessite has been found in the Hodgkiss lode, on the divide between Uncompahgre and Animas Rivers. A similar one is reported from the vicinity of Parrott City, on the La Plata. Prof. B. Silliman examined a specimen from the Red Cloud Mine,† and found: Au, 7.131 per cent.; Ag., 51.061 per cent. A specimen of hessite from the Red Cloud Mine, analyzed by Genth,‡ showed the following composition:

	Per cent.
Gold	0.22
Silver	59.91
Copper	0.17
Lead	0.45
Zinc	trace.
Iron	1.35
Tellurium	37.86

* Rep. U. S. Geol. Surv., 1873, p. 353.

† Rep. U. S. Geol. Surv., 1873, p. 689.

‡ Proc. Am. Phil. Soc., Phila., vol. xiv., p. 227, 1876.

HESSITE, AURIFEROUS.—Genth has published* three analyses. One of these gives the following results:

	Per cent.
Quartz	0.70
Gold	13.09
Silver	50.56
Copper	0.07
Lead	0.17
Zinc	0.15
Iron	0.36
Tellurium	34.91
	100.01

HEULANDITE.—Small crystals in basalt near Uncompahgre Park.
HITCHCOCKITE.—*See* PLUMBOGUMMITE.
HORNBLENDE.—*See* AMPHIBOLITE.
HYALITE.—*See* OPAL.
HYPERSTHENE.—In some of the dikes of the Front Range.
IDOCRASE.—*See* VESUVIANITE.
IODYRITE.—A small fragment was found in some surface ore from the Red Cloud Mine, Gold Hill.
IRON.—Native in the Colorado meteorite found in 1866.
ISERITE.—Chug Water.
JAMESONITE.—Sweet Home Mine, San Juan. Summit district, near Del Norte.
JAROSITE.—On the dumps of the Wood Mine, Leavenworth Gulch, near Nevada.
JASPER.—*See* QUARTZ.
JET.—Wet Mountain Valley, Trinchera Mesa, Southeast Colorado. Occurs in narrow seams in most of the coal-bearing beds.
KALINITE.—See ALUM.
LABRADORITE.—Near Golden, in the dolerites. Near Fair Play, in the trap-rock. In the dolerites of Colorado, generally. No good crystals.
LANARKITE.—(Mine unknown, but probably in South Park.)
LEAD.—Native in Hall Gulch, Summit County. At Breckenridge. An announcement of native lead must always be received with necessary caution. The small specimen owned by Professor Schirmer I have seen, but although it had a very "natural" appearance, I was unable to decide.
LEPIDOLITE.—Rito Alto Peak, in a form resembling the Saxon zinnwaldite.
LEUCITE.—Table Mountain, Golden City.
LEUCOPYRITE.—Spanish Bar.
LIGNITE.—Mouth of Gunnison. There it retains its wood structure.
LIMONITE.—In the Tertiary sandstone, west of Plum Creek, near Colorado City; in several localities of South Park. At the head of South Fork of Anthracite Creek, west slope of Sangre de Cristo Range, above Mosco Pass. Numerous localities in White River region. The "kidney-ores" of lignitic group. Pseudomorphous after pyrite crystals at Central, Gilpin County.
LIONITE.—From the Mountain Lion Mine, Magnolia district. Professor Genth furnishes two analyses of the mineral.†

* Rep. U. S. Geol. Surv., 1873, p. 689.
† Zeitschr. für Kryst. und Min., P. Groth, vol. II, No. 1, 1877. It is essentially a modification of tellurium (*q. v.*), and is intimately associated with quartz.

Analyses:

	(1.) Per cent.	(2.) Per cent.
Au	1.38	1.53
Ag	0.25	0.25
Te	55.86	55.54
$Si O_2$	34.72	35.91
$Al_2 O_3$, $Fe_2 O_3$	6.15	6.14
Mg O	0.17	0.19
Ca O	0.48	0.26
Total	99.01	99.82

MAGNESITE.—In small quantities in the Running lode at Black Hawk.

MAGNETIC IRON.—Bear Creek, Ralston Creek, Grape Creek.

MAGNETITE.—In loose nodules on Gunnell and Procer Hills, at Central; in small octahedric crystals in the gneissic rock on station 1. Occurring in the granites of various localities, Silver Hills, White House, Capitol; in the dolerite rocks generally. At Idaho and Caribou. Occurs near Golden. Octahedral crystals on Quartz Hill, near Central. On Grape Creek, near Cañon City, is an extensive deposit of magnetite, which is mined as iron ore.

MAGNOLITE.—From the Keystone Mine. It occurs, according to Genth,* in capilloid and acicular crystals. It is the result of decomposition of coloradoite, and has the formula Hg_2, TeO_4.

MALACHITE.—Is found as the result of decomposition of fahlerz and other minerals at the Dallas, Leavenworth, and other mines near Central; at the No-Name, Caribou, Seven-Thirty, Fourth of July, and others, at Caribou; at some of the Georgetown mines; at the Hardscrabble mines, on Mount Princeton, and other localities; at Crater Mountain, in the mines of Fair Play and Elk Mountain district. Malachite lode, Bear Creek, Gendhemas lode, Tucker's Gulch, Oro City, Cañon City, Pollock, Montezuma. Allen's copper mine, head of San Luis Valley.

MARCASITE.—Philipps Mine, Fair Play.

MELACONITE.—Occurring at the Gunnell, Briggs, Leavitt, Leavenworth, and other mines near Central; at the Unknown Mine, in Montgomery, Tucker's Gulch, Jefferson County, Colorado. Pollock, Mosquito.

MELANTERITE.—On the dumps of the Wood, Dallas, and Kansas mines, and others, near Central; in the Sweet Home Mine.

MERCURY.—Native; associated with mercury-telluride in the Sunshine district, Boulder County.

MESITITE.—Black Prince lode, Lump Gulch.

MESOLITE.—Golden, Colo., South Table Mountain.

MISPICKEL.—*See* ARSENOPYRITE.

MINIUM.—Freeland Mine, Trail Creek, Georgetown, Central City. Dutchman lode, San Juan district.

METEORIC IRON.—*See* IRON.

MOLYBDENITE.—Leavitt mine, at Central; occurring in thread-like veins in Silver Hills, near Fair Play, Boulder County. Douglass Tunnell, Georgetown; Alice Cary lode, San Juan district.

MOLYBDITE.—Alice Carey lode, San Juan district.

MUSCOVITE.—In good crystals on Mount Ouray, and in the coarse-grained granite near Cañon City; throughout the granite and partly in the schist rocks. Fine crystals from Topaz Buttes.

NAGYAGITE.—Gold Hill. This mineral is rare, and its identity is scarcely fully established.

*Zeitschr. für Kryst. und Min., P. Groth, vol. II, No. 1, 1877.

NATROLITE.—Golden, Colo. Table Mountain. In cavities in the Basalt near Uncompahgre Peak.

OBSIDIAN.—Porphyritic, in a dike, at station 27 of 1873; Buffalo Peak, Arkansas Valley, and Union Park. Under the trachyte, on Gunnison River (porphyritic and spherulitic). A heavy vein of porphyritic obsidian occurs near the Rio Grande Pyramid, and continues from there southward in the trachytic beds. Nodules occur in the lower members of the trachytic series. A dike of obsidian, light-gray, clear sets across the Colorado Central lode near Georgetown. North of Saguache Creek with concentric structure.

OLIGOCLASE.—Occurs in many of the granites and in the volcanic rocks of Colorado. Good crystals are rare.

OLIVINE.—Transparent, green in the basalts of San Luis Valley.

ONYX.—*See* QUARTZ.

OPAL.—Aguas Calientes, Gilson Gulch; Idaho Springs, here the Opal occurs in narrow seams in the granite; mostly it is brownish; milk-white at Colorado Springs.

Semi-opal.—Found together with the Chalcedonies at the Los Piños agency. North of Saguache Creek in trachyte.

Wood opal.—On Cherry Creek, near Florissant, South Park.

Hyalite.—In the trachytes, near the Los Piños agency. At the Hot Sulphur Springs, Middle Park. Basalt of North Mam. Sometimes occurring in very fine specimens in the trachorheites of the Uncompahgre groups.

ORTHOCLASE.—Occurs in very fine, though small crystals, on Bobtail and Gregory Hills at Central. Crystals there are either simple or Carlsbad twins. It is found in very large pieces in some of the coarse-grained granites. Near Mount Ouray this is particularly the case. Large tablets of flesh-colored orthoclase can there be found. Crystals of large size, simple and twins, occur in the porphyritic dikes at Gold Hill, Boulder County, at the head of Chalk Creek, interlaminated with oligoclase in the porphyritic protoginyte. Crystallized in Jefferson County; greenish in South Park, west of Pike's Peak; reddish on Elk Creek; brown and gray at various localities near Central City. Beautiful, green crystals of orthoclase are found on Bear Creek, near Pike's Peak, associated with smoky quartz. An analysis by Dr. Oscar Loew* of this orthoclase furnishes the following result:

	(1)	(2)
Silicic acid	67.01	63.12
Alumina	19.94	19.78
Protoxide of iron	0.89	1.51
Soda	3.15	2.11
Potassa	8.84	12.57
Lime	trace.	0.66
Magnesia	trace.	0.13
	99.83	99.88

The coloring of this orthoclase, therefore, is due to a small percentage of protoxide of iron.

Dr. G. A. Koenig† regards the coloring-matter of this green orthoclase as dependent upon a ferric compound, probably an "organic salt."

OZOCERITE ?—From head Cherry Creek.

*Ann. Rep. Expl. and Surv. West 100th Mer., App. L. L., 1875, p. 111.

†Proc. Ac. Nat. Sci., Phil., Part II, 1876, p. 155.

PARGASITE.—Small particles in quartz. In a dike north of Centreville.

PEGMATITE.—At several localities in the vicinity of Georgetown. Bear Creek and Gold Hill, in Boulder County. Mount Ouray.

PETROLEUM.—From the oil-wells in Oil Creek Cañon, to the east of Canyon City. Smoky Creek, 10 miles south of Golden.

PETZITE.—In the gold mines of Gold Hill, occurring in narrow seams and veins. This mineral occurs also in the other telluride districts. Reported from Lake district. An anlaysis published by Genth* furnishes the subjoined result:

	Per cent.
Quartz	0.62
Gold	24.10
Silver	40.73
Copper	trace
Bismuth	0.41
Lead	0.26
Zinc	0.05
Iron	0.78
Tellurium	33.49
	100.44

PHLOGOPITE.—Mount Princeton; probably a number of the small, splendent brown crystals in granites are phlogopite.

PICKERINGITE.—This mineral was found by Dr. John Le Conte near Monument Park. It is crystallized in thin needles. An analysis furnished E. Goldsmith the following result:†

	Per cent.
$Si\,O_2$	38.69
$Al_2\,O_3$	11.90
$Mg\,O$	4.89
$(Ka_2\,O\;Na_2\,O)$	0.68
Sand	1.90
By diff. $H_2\,O$	41.94
	100.00

PITCHBLENDE.—*See* URANINITE.

PLUMBOGUMMITE.—On lead and copper minerals of the Dallas lode near Black Hawk.

POLYBASITE.—In tabular crystals at the Terrible mine, near Georgetown, Clear Creek County.

PRASE.—*See* QUARTZ.

PREHNITE.—Fair Play, in some of the mines.

PROUSTITE.—Occurring in the Brown lode, intermixed with galenite.

PSEUDOMALACHITE.—Little Platte River, south of Fair Play.

PSILOMELANE.—Seaton Mine, Idaho; occurs in small quantities.

PYRARGYRITE.—In the Colorado Central, Terrible, International, Cold Stream mines, at Georgetown, associated with galenite, fahlerz, and sphalerite. In the Brown lode with galenite; Argentine, Georgetown; in many of the Georgetown silver mines; in the mines near Fair Play; in the mines of the San Juan district. Fine crystals occur in the Wheel of Fortune lode, Mount Sneffels district, San Juan.

PYRITE.—Pyrite is one of the most widely-distributed minerals of the State. It is found in all the mines of Gilpin County. It occurs in the Empire mining district, in the Gold Hill mines; in the Trinidad gold mining district; in the Summit district; in the San Juan and Lake districts; in Summit district; in the mining districts of South

* Proc. Am. Phil. Soc., Phil., Vol. XIV, p. 227, 1876.
† Proc. Am. Nat. Sci., Phil., Part III, 1876, p. 333.

and North Parks. Mostly it is auriferous and associated with chalcopyrite. Found both massive and crystallized. Massive in the Leavitt, Briggs, Kansas, Bobtail, and other mines near Central. Large bodies of it occur in the Mammoth, Gunnell, Grand Army, and other lodes near Central. Cubes in combination with the pentagonal dodecahedron are found in the Winnebago, Mack, Dallas, Kansas, Grand Army, Gunnell, and other mines at Central. Crystallized and massive in the mines of Silver Hills, Buckskin, Idaho; in the Tenth Legion mine at Empire; in the Elk Mountain district. Cubes are found in the Granite of the Mount Princeton group, on Eagle River in the mines of Summit district. Cubes of four to five inches edge in the Phillips mine. Cubes and octahedra, simple and in combination in the San Juan district. Pentagonal dodecahedra in the Bobtail and Briggs at Central. Octahedra at the head of the Uncompahgre. Octahedra on Anthracite Creek.

Radiated pyrite (possibly *Markasite*).—Smoky Hill River; Purgatory, Apishpa Creek.

PYROLUSITE.—Massive at Buckskin and in Silver Hills. Eureka Gulch near Howardsville, San Juan.

PYROMORPHITE.—Freeland lode, Trail Creek.

PYROXENE.—Near Fair Play. In a number of localities in younger volcanic and metamorphic rocks. Crystals in the basalts of Southern San Luis Valley.

PYRRHOTITE.—Malachite lode, Jefferson County. Nevada district, Gilpin County.

QUARTZ.—Occurs massive in some of the very coarse-grained granites. Many of the quartz-veins are almost or totally devoid of ore, in which case the quartz is generally milk-white and pure.

Crystals, very pretty quartz crystals, small; occur on Quartz Hill near Central. The Bobtail, Gunnell, Briggs, and other mines near Central furnish good, small crystals. In the Rosita lodes and in some of the mines of Georgetown. On East River; in the mines of the Elk mountain district; Iowa Gulch; Sopris Peak; head of Anthracite Creek. Good crystals with many combinations of the pyramidal faces are found on Topaz Butte. Dihexahedral crystals occur in the porphyry of the Sangre de Cristo range and in the rhyolite near Uncompahgre Peak. At Spanish Peaks.

Smoky quartz.—The locality on Bear Creek near Pike's Peak has become well known on account of its smoky quartz crystals associated with green orthoclase. Large crystals, reaching over a foot in length, are there found, in cavities of the granite. Crystals are also found on Elk Creek and on the Upper Platte.

Rosy quartz.—Occurs at many localities in Colorado, in the granites. Good specimens can be obtained from the head of Roaring Fork. Found, also, near Clear Creek, and on Bear Creek.

Amethyst.—Small crystals at Nevada and neighboring localities; on Rock Creek; Clear Creek County; on the summit of the range east of the Animas.

Agate.—Fine specimens, lined with amethyst, on the summit of the range east of the Animas. Cloudy, of white and gray color, in the lower trachytic formations of the Uncompahgre group; in various forms, cloudy, banded, laminated, and variegated, at the Los Pinos agency. In South Park, in the drift; in the Lower Arkansas Valley; on the Frying Pan; throughout Middle Park; on the Lower Gunnison and adjacent regions.

Moss-agate.—Below the Uncompahgre, near Grand River.

Chalcedony.—Chalk Hills, eight miles south of Cheyenne Mountain; at the Los Pinos agency; on the bluffs near Wagon-Wheel Gap; along the Upper Rio Grande Valley; in Middle and South Parks; Buffalo Park; Fair Play; Frying Pan; Front Creek; Gunnison River. Found frequently in drift accumulations.

Flint.—Occurs together with chalcedony. Found very frequently in the lower members of the trachytic series.

Aventurine quartz.—On Elk Creek.

Chrysopase.—Rare in Middle Park.

Carnelian.—Middle and South Parks; Los Pinos agency.

Onyx.—Middle Park.

Sardonyx.—Middle Park.

Basanite.—East of the salt-works in South Park. It is found, together with flint, in some of the trachytes.

Prase.—Middle Park.

Jasper.—Green and red, station 33 of 1873. Yellow, red, brown, and gray at the Los Pinos agency. Throughout Middle and South Parks; along the Gunnison, Dakota group, Arkansas, Grand, White, Animas, and other rivers in the drift. Occurs also in some of the trachytes, mostly red, brown, and green. The best locality for this horizon is at the junction of Lost Trail Creek and the Rio Grande.

Siliceous sinter.—South Park.

QUICKSILVER.—*See* MERCURY.

RHODOCHROSITE.—Sweet Home Mine, Park County, in very beautiful specimens; in the Diadem Mine.

RHODONITE.—Eureka Gulch, near Howardsville; San Juan.

RIPIDOLITE.—Trail Creek, Clear Creek County, Colorado. In the Little Giant lode, Arastra Gulch, and in the Crystal Lode, Silverton.

ROSCOLITE.—A greenish mineral, intimately associated with quartz, found at the Keystone and Mountain Lion Mines, in Boulder County. Genth publishes an analysis,* with the following result:

	Per cent.
$Li\ O_2$	57.15
$Al_2\ O_3$	19.94
$V_2\ O_3$	8.44
$Mn\ O$	trace
$Fe\ O$	3.51
$Mg\ O$	2.87
$Li_2\ O$	trace
$Na_2\ O$	0.94
$K_2\ O$	8.11
$H_2\ O$	not determined
	100.96

RUTILE.—On the Ute pass, occurring in quartz.

SANIDITE.—Occurs throughout the trachorheïtes, sometimes in very handsome crystals. Wherever the trachytes have been reheated the sanidite is adularizing.

SARDONYX.—*See* QUARTZ.

SCHAPBACHITE.—Occurs near Georgetown.

SCHEELITE.—Crystals are reported from some of the mines near Baker's Park.

SCHIRMERITE (Endlich).—Red Cloud and Cold Spring Mine, Gold Hill. Occurs also in the other telluride districts. A specimen from the Red Cloud furnished,† gold, 18.82; silver, 28.60 per cent. (*See* PETZITE.)

* Zeitschr. für Kryst. und Min. P. Groth, vol. ii, No. 1, p. 11, 1877.
† Rep. U. S. Geol. Surv., 1873, p. 354.

SCHIRMERITE (Genth).—With tellurides at the Red Cloud Mine, Gold Hill. An analysis by Professor Genth furnished:*

	(1) Per cent.	(2) Per cent.
Pb	12.69	12.76
Ag	22.82	24.75
Bi	46.91	47.27
Zn	0.08	0.13
Fe	0.03	0.07
S	14.41	15.02
	96.94	100.00

SCHREIBERSITE.—In the Colorado meteorite.
SELENITE.—*See* GYPSUM.
SEMIOPAL.—*See* OPAL.
SERPENTINE.—Small specimens of serpentine occur in the metamorphic rocks of Mosco Pass.
SIDERITE.—Crystallized in South Park, Gold Hill, Colo.; Veto lode, Gibson Gulch; Rob Roy lode, Central City. At the Rosita mines.
SILVER.—Native, as wire-silver, at the Terrible, Georgetown; at the International, on Mount McClellan; as wire-silver in the No-Name and Caribou mines, at Caribou. In small nuggets and thin scales near Fair Play in Washington Gulch, Homestake lode; Sunshine; Gold Hill; Blue River, Montezuma; Jones Mountain and Mount Sneffels, San Juan.
SINTER CALCAREOUS.—*See* TUFA.
SINTER-SILICEOUS.—*See* QUARTZ.
SMITHSONITE.—Jones's Mine on sphalerite, near Central, Running lode, Black Hawk.
SODA.—Carbonate, from the Hot Springs.
SODIUM-CHLORIDE.—*See* HALITE.
SODA-SULPHATE.—*See* GLAUBER-SALT.
SPESSARTITE.—*See* GARNET.
SPHALERITE.—Occurs in almost every mine; only few exceptions take place. In the lead-silver mines it is more abundant than in the gold mines. It is found in the Winnebago, dark brown, Dallas, Gunnell, J. P. Whitney, Kansas, Wood, California, Running, Bobtail, Briggs (small quantities in these two), Monte Cristo, and numerous other mines in the vicinity of Central. The mines of Georgetown invariably contain it. The Caribou mines show at times large quantities of the mineral. Mount Princeton: sphalerite, containing cadmium, found in several mines near Fair Play. Occurs in nearly all the mines of the San Juan region. Varies in color from greenish yellow to brown and black. Brilliant crystals are found in the Terrible lode at Georgetown.
SPINEL.—Crystal Mine, Virginia Cañon.
STAUROLITE.—Simple and twin crystals in the micaceous schists near Mount Oso, Quartzite Mountains.
STERNBERGITE (iron and silver sulphide).—Georgetown. (Loew.)
STEPHANITE.—Colorado Central, Georgetown, Moose Mine, near Fair Play, Montezuma, and other localities.
STIBNITE.—Terrible Mine, near Georgetown, Boulder County.
STILBITE.—Very fine crystals in cavities of basalt, near Uncompahgre Peak.

* Proc. Phil. Soc. Phila., xiv, p. 230.

SULPHUR.—In small crystals on galenite from the Clifton Mine, near Central; found in Middle Park, Pagosa Springs. Sometimes found in narrow seams in galenite, the result of decomposition of the latter.

SYLVANITE.—In the Red Cloud Mine, of Gold Hill, occurring in foliated masses and thread-like veins. In crystals and crystalline masses in the Sunshine district. According to Professor Silliman* the ratio of gold and silver for a specimen from the Red Cloud, is, gold 1.7 to silver 1.0. Professor Genth publishes an analysis of sylvanite obtained from the Red Cloud Mine,† showing the following composition:

	Per cent.
Quartz	0.32
Gold	24.83
Silver	13.05
Copper	0.23
Zinc	0.45
Iron	3.28
Tellurium	56.31
Selenium	trace.
Sulphur	1.82
	100.29

TALC.—In fine scales among the gangue-rock of the Bobtail and Kansas, near Central. In light pink scales in the Silver Hills and Barton mines, Hardscrabble district. In Mosco Pass.

TELLURITE.—A new species described by Dr. Genth.‡ It is the result of decomposition of tellurium and sellurides. Its formula is $Te\ O_2$. Found in the Keystone, Smuggler, and John Jay mines in small crystals.

TELLURIUM, NATIVE.—At the Red Cloud Mine, of Gold Hill, in crystalline masses, belonging to the hexagonal system. The largest specimen known was obtained by Professor Schirmer from the Red Cloud Mine. It weighed about five pounds, and consisted in a mixture of quartz and tellurium. Upon examination§ it was found to contain 90.85 per cent. of tellurium, small quantities of selenium, iron, and bismuth, and traces of gold and silver. Professor Silliman‖ did not find any selenium.

Genth publishes an analysis of tellurium from the Magnolia district, Boulder County.¶

Au	0.60
Ag	0.07
Te	96.91
$V_2\ O_3$	0.49
$Fe\ O$	0.78
$Hg\ Al_2\ O_3\ Mg\ O\ K_2\ O$, &c	1.15
	100.00

TENNANTITE.—Crystals in Buckskin Gulch; Geneva district; Park County. Freeland Mine, Clear Creek County.

TETRAHEDRITE.—Crystals in Buckskin Gulch. Fine crystals in the Clifton lode, Central City. Crystals in the Colorado Chieftain lode, San Juan district. Massive in a number of the San Juan silver-mines.

* Rep. U. S. Geol. Surv., 1873, p. 690.
† Proc. Am. Phil. Soc., Philadelphia, vol. xiv, p. 288, 1876.
‡ Zeitschr. für Kryst. und Min. P. Groth, vol. ii, No. 1, p. 7, 1877.
§ Compare Rep. U. S. Geol. Surv., 1873, p. 355.
‖ Ibid., p. 685, and Am. Jour. Sci. xlii, p. 571.
¶ Zeitschr. für Kryst. und Min. P. Groth, vol. ii, No. 1, 1877.

TORBERNITE.—(URANITE.) Found by Captain Berthoud on Lyden Creek.* Probably mostly decomposed. Found on Griffith Mountain, Clear Creek County.

TOURMALINE.—In the quartz of Gunnell Hill, near Central; on Running Hill, at Black Hawk; on Guy Hill, and at Nevada; in quartz north of the Arkansas River. Crystals with both terminations at Montgomery; on Ralston Creek. All tourmaline of Colorado is either black or dark brown.

TREMOLITE.—Smith's Fork of the Gunnison River.

TUFA.—Calcareous. On Currant Creek; Roaring Fork; Frying Pan. At the mineral springs of White Earth, Wagon-Wheel Gap, Pagosa, Animas, and in Uncompahgre Park.

TURQUOISE.—Southern Colorado. (Doubtful.)

URACONITE.—Wood lode, Leavenworth Gulch, near Nevada.

URANINITE.—Occurs in large quantities, massive in the Wood lode, Leavenworth Gulch, near Nevada. An analysis by Dr. O. Loew † furnishes the following result:

Uranoso-uranic acid	11.37
Sulphides of iron and copper	45.81
Gangue (quartz by difference)	42.82

URANOCHALCITE.—Wood lode, Leavenworth Gulch, near Nevada.

VESUVIANITE.—In large crystals of simple combinations on Mount Italia. North of Arkansas River, in the granite.

WAVELLITE.—South Table Mountain, at Golden.

WHEELERITE.—Described by Dr. Oscar Loew.‡ This mineral, which is quoted from New Mexico, probably also occurs in the coal of Colorado. It is a resin, related to amber. Its existence in each particular instance, however, can only be determined by analysis, on account of its physical resemblance to other resins occurring in the same manner. The analysis of Wheelerite by Loew furnishes:

	(1) Per cent.	(2) Per cent.
Carbon	73.07	72.87
Hydrogen	7.95	7.88
Oxygen	18.98	19.25

WILLEMITE.—Jones's Mine, Central City.

WOLFRAMITE.—Reported from Southern Colorado.

WOLLASTONITE.—Occurs in small quantities in some of the limestones near Fair Play.

WULFENITE.—Is found in Park County; at Gold Hill, Boulder County.

XENOTIMITE.—Reported from Cheyenne Mountain.

ZINCITE.—Jones's Mine, Central City.

ZIRCON.—Bear River; Middle Park. In small crystals. Crystals of zircon are found in the feldspar of Pike's Peak. Dr. G. A. Koenig § has furnished the following analysis:

	Per cent.
$Si\,O_2$	28.00
$Mg\,O$	8.93
$(Fe_2\,O_3)\,Zr\,O_2$	60.00
$H_2\,O$	3.47
	100.40

* Proc. Ac. Nat. Sci. Phil., Part II, 1875, p. 363.

† Rep. Expl. and Surv. West 100th Mer., vol. iii, p. 636.

‡ Rep. Expl. and Surv. West 100th Merid., vol. iii, p. 630, and Am. Jour. Sci., vol. xlii, p. 571.

§ Proc. Ac. Nat. Sci. Phil., Part II, 1876, p. 156.

Zircon has also been found in quartz in El Paso County. An analysis furnished Dr. Koenig the following result:*

	Per cent.
$Si O_2$	29.70
$Zr O_2$	60.98
$Fe_2 O_3$	9.20
$Mg O$	0.30
	100.18

ZINKENITE.—Sweet Home Mine, small crystals.

ZIPPEITE.—Wood lode, Leavenworth Gulch, near Nevada.

*Ibid., Part I, 1877, p. 9.

SYSTEMATIC ARRANGEMENT OF COLORADO MINERALS.*

I. NATIVE ELEMENTS.

Gold (1).
Silver (2).
Quicksilver (8).
Amalgam (9).
Copper (12).
Iron (13).
Lead (15).
Antimony (18).
Bismuth (20).
Tellurium (21).
Sulphur (22).
Graphite (25).

II. SULPHIDS, TELLURIDS, SELENIDS, ARSENIDS, ANTIMONIDS, BISMUTHIDS.

A. SIMPLE SULPHIDS, &C.

Stibnite (29).
Bismuthinite (30).
Molybdenite (34).
Dyscrasite (35).
Schapbachite (36 A).
Argentite (40).
Galenite (44).
Altaïte (48).
Bornite (49).
Alabandite (52).
Sphalerite (56).
Hessite (58).
Chalcocite (61).
Sternbergite (63).
Pyrrhotite (68).
Greenockite (69.)
Schreibersite (74).
Pyrite (75).
Chalcopyrite (78).
Chloanthite (83.)
Marcasite (90).
Leucopyrite (91).
Arsenopyrite (94).
Sylvanite (98).
Calaverite.
Nagyagite (99).
Covellite (100).

B. DOUBLE SULPHIDS, &C.

Zinkenite (106).
Jamesonite (112).
Schirmerite (112 A).
Freieslebenite (114).
Pyrargyrite (117).
Proustite (118).
Bournonite (119).
Tetrahedrite (124).
Tennantite (127).
Stephanite (130).
Polybasite (131).
Enargite (132).

III. COMPOUNDS OF CHLORINE, BROMINE, IODINE.

Halite (138).
Cerargyrite (140).
Embolite (141).
Iodyrite (143).
Carnallite (147).
Atacamite (153).

* The classification herein adopted is that given by Dana in his "System of Mineralogy." The numbers placed in parentheses after the mineral-names, correspond to the numbers given by Dana.

IV. FLUORINE COMPOUNDS.

Fluorite (159). (Chlorophanite).

V. OXYGEN COMPOUNDS.

A. OXYDS.

1. Oxyds of elements of series I.

A. Anhydrous.

Cuprite (172).
Zincite (176).
Melaconite (178).
Hematite (180).
Iserite (181 A).
Spinel (183).
Magnetite (186).
Franklinite (188).
Chromite (189).
Uraninite (190).
Rutile (193).
Minium (197).
Pyrolusite (199).

B. Hydrous.

Goethite (204).
Limonite (206).
Brucite (210).
Psilomelane (217).

2. Oxyds of elements of series II.
Molybdite (224).

3. Oxyds of carbon-silicon group.
Quartz (231).
Opal (232).

A. TERNARY OXYGEN COMPOUNDS.

1. SILICATES.

A. Anhydrous.

Hypersthene (235).
Wollastonite (237).
Pyroxene (238).
Rhodonite (241).
Anthophyllite (246).
Amphibolite (247).
Arfvedsonite (248).
Beryl (254).
Chrysolite (259).
Willemite (266.)
Garnet (271).
Zircon (272).
Vesuvianite (273).
Epidote (276).
Phlogopite (288).
Biotite (289).
Astrophyllite (292).
Muscovite (293).
Lepidolite (294).
Leucite (309).
Labradorite (311).
Andesite (312).
Oligoclase (314).
Albite (315).
Orthoclase (316).
Tourmaline (320).
Staurolite (333).

B. Hydrous.

Chrysocolla (346).
Calamine (361).
Prehnite (363).
Apophyllite (370).
Allophanite (374).

Zeolite section.

Natrolite (378).	Chabazite (386).
Mesolite (381).	Stilbite (392).
Analcite (383).	Heulandite (394).

Margarophyllite section.

Talc (399).	Caolinite (419).
Serpentine (411).	Ripidolite (450).

2. COLUMBATES.

Columbite (474.)

3. PHOSPHATES.

A. Anhydrous.

Xenotimite (490).	Pyromorphite (493).
Apatite (492).	

B. Hydrous.

Pseudomalachite (543).	Turquoise (563).
Wavellite (554).	Torbernite (572).
Plumbogummite (556).	

4. TUNGSTATES AND MOLYBDATES.

Wolframite (610).	Wulfenite (617).
Scheelite (614).	

5. SULPHATES.

A. Anhydrous.

Barite (630).	Caledonite (636).
Anhydrite (632).	Glauberite (640).
Anglesite (633).	Lanarkite (641).

B. Hydrous.

Gypsum (654).	Aluminite (688).
Melanterite (664).	Jarosite (691).
Goslarite (666).	Glockerite (696).
Chalcanthite (669).	Uranochalcite (706).
Kalinite (674).	Zippeite (708).
Pickeringite (678).	Uraconite (710).

6. CARBONATES.

A. Anhydrous.

Calcite (715).	Rhodochrosite (722).
Dolomite (716).	Smithsonite (723).
Magnesite (718).	Aragonite (724).
Mesitite (719).	Cerussite (729).
Siderite (721).	

B. Hydrous.

Trona (738).	Azurite (752).
Malachite (751).	Bismutite (753).

VI. HYDROCARBON COMPOUNDS.

Ozocerite (780).	Asphaltum (830).
Succinite (799).	Mineral coal (831).

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REPORT OF A. C. PEALE, M. D., GEOLOGIST OF THE GRAND RIVER DIVISION, 1876.

LETTER OF TRANSMITTAL.

WASHINGTON, D. C., *December* 28, 1877.

SIR: I have the honor herewith to hand you my report as geologist of the Grand River division for the season of 1876.

The division was in the field just two months, of which thirty-two days were occupied in the work. During this time the area actually examined so that its general geology can be mapped is about 4,000 square miles.

The district assigned us consists of two widely separated areas, partially reported on in previous reports. Both are remote from settlements, and hence almost half the time the division was in the field was necessarily occupied in marching to and from the areas.

In the geological investigation of these detached areas (which in the report are designated as areas A and B) difficulty was experienced from the limited amount of time, owing to the lateness of the season. Owing to this cause also another difficulty was met with, the lack of water. Both areas are desert-like, even at the best, and it is utterly impossible to study them in detail unless the work be undertaken in the spring and early summer, when the streams contain water.

Fortunately, however, the geological structure was found to be comparatively simple, as the sketches accompanying the report show. Had it been otherwise, the character of the country, and the rapidity with which we were obliged to travel over it would have precluded the possibility of coloring the map.

In the report I have followed my usual plan, considering first the general features, and afterward the special geological facts relating to the district. The geological map and general sections for the Atlas of Colorado have been prepared.

For the illustrations accompanying the report I am indebted to Mr. W. H. Holmes and Mr. F. D. Owen. The profiles of the sections are based on the topographical work of Mr. Henry Gannett, to whom also I am indebted for the accompanying maps.

With great respect, I have the honor to remain your obedient servant,

A. C. PEALE.

Dr. F. V. HAYDEN,
United States Geologist, in charge.

GEOLOGICAL REPORT ON THE GRAND RIVER DISTRICT.

CHAPTER I.

GENERAL INTRODUCTION.

The area assigned to the Grand River Division for 1876 was divided into two parts. First was a district of about 1,000 square miles south of the Sierra la Sal, between the Dolores and San Miguel Rivers, and extending south as far as the parallel of 38°. The larger portion of the area, consisting of about 3,000 square miles, lies north of Grand River, extending from the river as a southern line, northward to the parallel of 39° 30′, bounded on the east by the meridian of 108°, and on the west by 109° 30′.

Sedimentary formations prevail in both districts. The area (area A) south of the Sierra la Sal is the portion not completed in 1875, on account of the difficulty with the Indians, and it is the area first worked in 1876, nine days being devoted to it. A general view (Fig. 1, Plate X), obtained from the summit of Lone Cone, shows it to be plateau-like in general, cut by deep gorges or cañons toward the east, and rendered somewhat irregular toward the west by several broad folds. Near Lone Cone Mountain the country is somewhat hilly, and in places mesa-like. Here the Cretaceous shales (Middle Cretaceous) are seen resting on the Dakota group, which in general forms the floor of the plateau. The streams cut through the Dakota group exposing the Jurassic shales, especially toward the north, and as we follow the streams we find them cutting deeper and deeper, until the Red Beds (Trias?) appear beneath the Jurassic. West of the San Miguel Plateau, beyond Naturita Creek, the Dakota sandstones rise in a fold, the axis of which is northwest and southeast. Toward the northwest this fold is marked by the Paradox Valley, which appears to occupy its axis. Beyond Paradox Valley is the Basin Plateau. This is a gentle synclinal basin; for the strata on the west side of Paradox Valley dip gently to the southwest and, beyond the centre of the basin, rise again gently to the edge of the bluffs forming the eastern or northeastern wall of Gypsum Valley, which is similar to Paradox Valley. Between Gypsum Valley and the Dolores River is another synclinal basin, the sides of which dip southwest and northeast. At the northwestern end there is a dip to the southeast, which gives a saucer-like shape to the valley. From this fact we called it Saucer Valley. Around the northwestern end or rim of this valley the Dolores flows in a cañon, emerging from it into Gypsum Valley. Southwest of the Dolores the country rises into the northern border of the Sage Plain. In working up this area we took the following routes: From the crossing of the San Miguel we travelled northwestwardly along Naturita Creek, reaching the San Miguel again

below the great bend, and just above the point where it turns again to the northwest. From this bend we crossed to the head of Paradox Valley, down which we followed a few miles; thence we travelled southward across the Basin Plateau, and a little southwest across Gypsum Valley and Saucer Valley to the Dolores. Returning, we crossed the head of Gypsum Valley, and, skirting the country near the northern slopes of Lone Cone, turned north to the crossing of the San Miguel, having completed the circuit of the area.

Four days' travel from the Uncompahgre Indian agency, on the Uncompahgre River, brought us into our northern district (area B). The southern line of this area is Grand River, which, after it is joined by the Gunnison, curves around the northern end of the Uncompahgre Plateau, flowing at first northwest and afterward southwest. In this area the geological formations extend uninterruptedly from the Red Beds (Trias?) exposed on the Grand, to the Tertiary strata outcropping at the summit of the "Roan" or "Book Cliffs."

Grand River is, for the most part, in a low cañon in the Red Beds. On the north side, the Dakota sandstones, with the underlying shales form low hogbacks, dipping away from the river toward the cliffs. Between the crest of the hogbacks and the foot of the cliffs is a broad valley, formed by the erosion of the soft shales of the Middle Cretaceous. These shales extend to the base of the cliffs, and in some places form their lower portion. The cliffs rise in steps to the summit, which has an elevation of 8,900 to 9,000, rising about 4,000 feet above the level of Grand River. The summit of the cliffs is the southern edge of a plateau, sloping northward to White River (Dr. Endlich's district). The strata in the cliffs are Tertiary sandstones and shales, through which the streams flowing to White River rarely cut deep enough to expose the Cretaceous.

Our line of travel through this district was as follows:

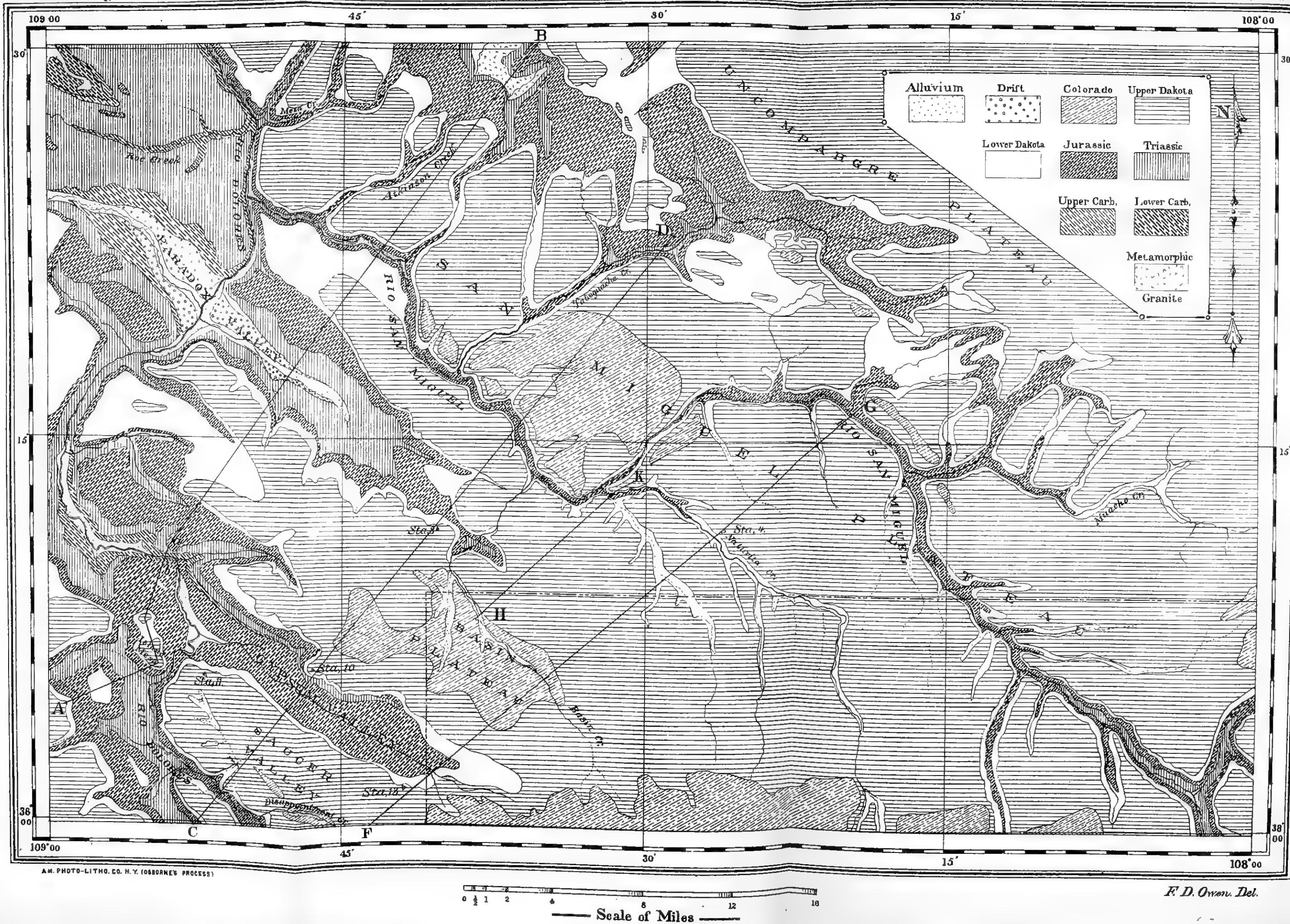
Crossing the Grand on the wagon-ford above the mouth of the Gunnison, we followed the road (which keeps on the north side of the river) nearly to the mouth of the Dolores. We then crossed the Grand River Valley to where Desert Creek emerges from the cliffs. From this point we followed the Indian trail, which leads up the western branch, to the summit of the cliffs. We then turned eastward on the trail, which follows the crest of the divide between the Grand River and White River drainage, leaving it at the head of Roan Creek. This latter stream was followed to the Grand, up which we travelled to Cactus Valley.

With this our work ended, the northern portion having taken twenty-three days to complete. The area included is about 3,000 square miles, while area A included only about 1,000 square miles.

From Cactus Valley we proceeded to Rawlins Springs, on the Union Pacific Railroad, via the White River Indian agency.

We reached Rawlins on October 23, having been in the field just two months, nearly half the time being occupied in marching to and from and between our districts, on account of their remoteness from settlements.

Map of Area A,



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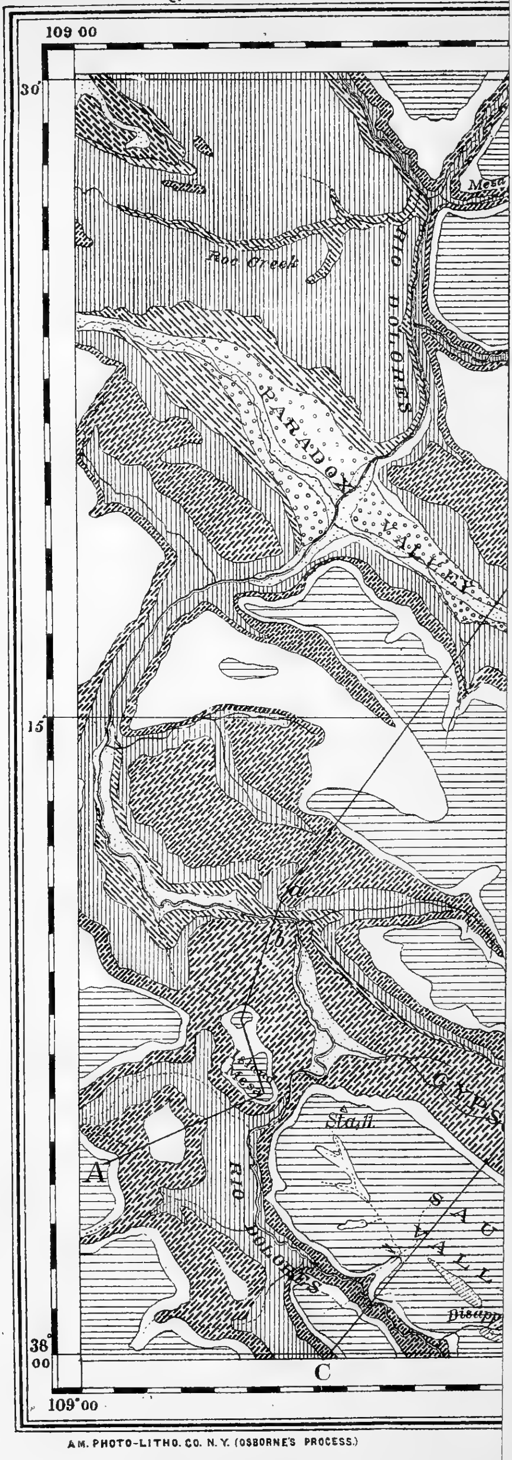

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CHAPTER II.

AREA A—SAN MIGUEL AND DOLORES RIVERS—SAUCER VALLEY—GYPSUM VALLEY—BASIN PLATEAU—PARADOX VALLEY—SAN MIGUEL PLATEAU.

Area A includes about 1,000 square miles, lying between the San Miguel and Dolores Rivers, and bounded on the south by the parallel of 38°. (See map, plate VIII.)

DRAINAGE.

The drainage of the area is by branches of the San Miguel and Dolores. The larger streams head in the Lone Cone group of mountains. The general direction is toward the northwest, and the changes in course are usually abrupt, many of the streams changing at right angles to their former courses. This gives a zigzag appearance to the drainage. The two general courses followed are northwest and northeast.

RIO SAN MIGUEL.

The Rio San Miguel was partially described in the Report for 1875, and little need be added here, except what is necessary to make the description of the area complete. The river forms the eastern and a portion of the northern boundary of the area. Where the Indian trail from Muache Creek crosses the river, the cañon is 800 feet in depth. The massive sandstones of the Upper Dakota group (Cretaceous) form the top of the cañon wall. The more shaly beds of the Lower Dakota group are exposed in places below, but are generally concealed by the *débris*, which is overgrown with pines and cedars. Whether there are any Jurassic layers outcropping it is impossible to say positively. Lower down on the river they undoubtedly occur. The river-bottom is very narrow, and in some places must disappear. There are cottonwoods (*Populus balsamifera*) and the growth of shrubbery common along the Western streams. The river is rapid, flowing over a rocky bottom.

From the crossing it keeps an almost northerly course to the mouth of Muache Creek, which comes in from the east. It then flows northwest for three or four miles, when it turns to westward, keeping this course for about seven miles. The next direction assumed is parallel to that of the streams rising in the crest of the Uncompahgre Plateau, viz., southwest. In this portion of its course the river emerges from its narrow cañon and flows through alluvial bottoms of considerable width—the walls on either side not being over 400 feet in height—composed of the Dakota sandstones, with cappings of the shales of the Middle Cretaceous.

About a mile and a half below the mouth of Naturita Creek the San Miguel turns to the northwest and flows in cañon to its mouth. The cañon at the head is 400 feet deep, and at the mouth 1,000 feet or more.

The rocks at first are the Dakota sandstones, which are rapidly cut through, Jura and Trias showing a short distance below Naturita Creek.

Naturita Creek rises on the northern and northwestern slopes of Lone Cone. The various small streams unite to form two branches, which soon join, and the stream thus formed flows nearly due north for about eight miles, when it turns nearly west, gradually turning to a northwest course.

The sources are in a beautiful park-like country underlaid with the Middle Cretaceous shales, which are soon cut through, exposing the Dakota group, the sandstones of which form the cañon walls to the mouth. The cañon becomes shallower as we go down the stream. Southwest of Station 4 it is about 500 feet deep, and at the mouth only some 200 to 300 feet. There is a narrow valley bordering the stream in this lower portion of its course. There is running water in it, probably, throughout the entire year. Below the bend are two unimportant branches that rise in the low divide separating Naturita Creek from Basin Creek. The creek was named from the abundance of the Spanish bayonet-plants (*Yucca angustifolia*), which the Indians call *Naturita* (the Spanish name). When we were in this region the plant was in fruit, and the Utes were gathering and drying it.

Basin Creek joins the San Miguel a few miles below the bend below Naturita Creek. It rises in the rolling mesa country northwest of Lone Cone, and flows northwestward across the Basin Plateau to within six miles of its mouth, when it turns abruptly at right angles and flows northeast to the Miguel, cutting across an anticlinal fold and a synclinal depression, with a fault on the east side. In the Basin Plateau the stream keeps near the eastern side of a synclinal depression, which is occupied by the Cretaceous shales. In this part of its course the stream is dry during the summer. Near the head, pools of alkali-water were found in September. From the Basin Plateau it turns at right angles and plunges into a cañon cutting across an anticlinal fold, in the centre of which the Red Beds (Trias?) are exposed. In this cañon the stream has running water, which sinks again when it emerges into the synclinal valley east of the fold. On the east side of this synclinal depression of Cretaceous shales, there is a fault with the down-throw on the west. This fault will be described under the head of Paradox Valley. Basin Creek cuts across this fault, and joins the San Miguel a short distance beyond.

Southwest of Basin Creek, the first creek of any importance is *Disappointment Creek*. In midsummer, water is found in it only in holes. It joins the Dolores on the southwest side of Saucer Valley.

RIO DOLORES.

The reports for 1875 describe the upper and lower parts of the Dolores. There was left undescribed, however, a gap of unexplored country through which the Dolores flows.

On the eastern side of the Great Sage Plain the general course of the Dolores is a few degrees west of north. It zigzags somewhat, flowing sometimes with the dip of the rocks and at others with the strike. It is in deep cañon for the most part in the Red Beds. On both sides of the river the beds dip to the eastward or northeast, and are capped with Jurassic (?) shales and Dakota sandstones and shales. On the west the country rises to the Great Sage Plain, which stretches away to the westward and southwestward. This region was visited by Mr. Holmes,

and will be described in his report. Below the mouth of Disappointment Creek the river is flowing toward the northwest, but it soon curves toward the north and east around the northwestern rim of Saucer Valled, and a short distance east of Island Mesa emerges into the lower part of Gypsum Valley. Island Mesa is capped with Dakota sandstones, a remnant of the strata forming most of the surface in Saucer Valley (see map of area A, Plate VIII).

North of the Mesa the river is seen flowing toward the west. It however soon turns to the north, and farther on curves again to the eastward, to the western side of Paradox Valley. In the portion of its course just referred to, the Dolores is bordered by red sandstones and shales, a portion of which ought probably be referred to the Upper Carboniferous. The cañon walls on both sides are bluffy, the upper beds of the bluffs being of Jurassic and Lower Cretaceous rocks. The adjacent country is mesa-like, gashed by streams tributary to the main river. But few of these gashes or cañons carry water during the summer months.

The Dolores cuts across Paradox Valley at right angles to its direction, and immediately plunges into the cañon that continues to its mouth. This portion of its course is described in the report for 1875.

The folds across which the river cuts its way are those of Gypsum Valley and Paradox Valley. Its course was therefore probably outlined before the folding took place, and the cutting of the cañon appears to have progressed gradually with the formation of the present folds.

SAUCER VALLEY.

At the lower end of the valley of Disappointment Creek is a saucer-like basin which gives name to the valley.

Through the western rim of this basin Disappointment Creek cuts its way to join the Dolores. The latter is in a monoclinal valley in Jura-Trias and flows around the northern rim of the basin.

The surface of Saucer Valley is composed mainly of Upper Dakota sandstones. In the centre are remnants of the Colorado shales which prevail so extensively farther up stream in the neighborhood of Lone Cone. Disappointment Creek cuts a deep gully in the soft shales. In September we found water only in pools in this gully. The drainage from the rim bordering the Dolores unites in a stream that cuts across the western rim about three miles north of Disappointment Creek. Near the sources of these streams or gullies, where the dip is greatest, beds of Lower Dakota age are exposed. The eastern, or rather northeastern rim (for the strike is northwest and southeast), is the southwestern border of Gypsum Valley.

GYPSUM VALLEY.

Gypsum Valley is named from the prevalence of gypsum in it, especially at its head. When first seen, the valley seemed to be a simple anticlinal, of which the centre had been eroded away. On the southwest is a hogback-like ridge 400 to 500 feet high. The Dakota sandstone forms the summit and southwestern slope of this hogback, dipping about 15° to the southwest. Beneath this, and presenting the edges of the strata to the northeast, are the shales of the Lower Dakota group, which pass below into the Jurassic. The soft character of the strata has caused the valley to become filled with *débris* which conceals the greater portion of the underlying strata.

On the northeast side of the valley is another bluff, which faces the southwest. This also is capped with Dakota sandstones, which dip 10°–15° to the northeast. The angle soon decreases and the beds form the floor of the Basin Plateau.

At Station 10 the sandstones are nearly 1,400 feet above the valley, and below them the Jurassic shales and Triassic red sandstones outcrop. It is probable that a portion of the Upper Carboniferous also shows. Following the ridge to the northwest it is noticed that the dip toward the northeast becomes less, and the country is more mesa-like. At a point a little east of north from Island Mesa, at the westward bend of the Dolores, on the north side (see *a* in Fig. 1, Plate IX), there are evidences of an anticlinal fold, the axis of which is on a line with the edge of the bluffs on which Station 10 is located. At the station there is no fold. At several points on the opposite ridge, however, there are obscure evidences of a fold, but the beds in the centre of the valley have been completely eroded away. Northeast of Island Mesa the Jurassic rocks show the folding as indicated at *b* in the section. (Fig. 1, Plate IX.) Whether the lower part of the valley is a synclinal or not is difficult to determine. I am inclined, however, to think not, but that the condition is folding and faulting, as represented in the section. The eastern fold dies out to the southeast, although the fault continues. This also dies out, or rather changes to a fold, for at the head of the valley the sandstones of the Dakota group are seen curving around to connect with those of the southwestern ridge. There is considerable obscurity here, resulting from the soft character of the strata, owing largely to the presence of gypsum.

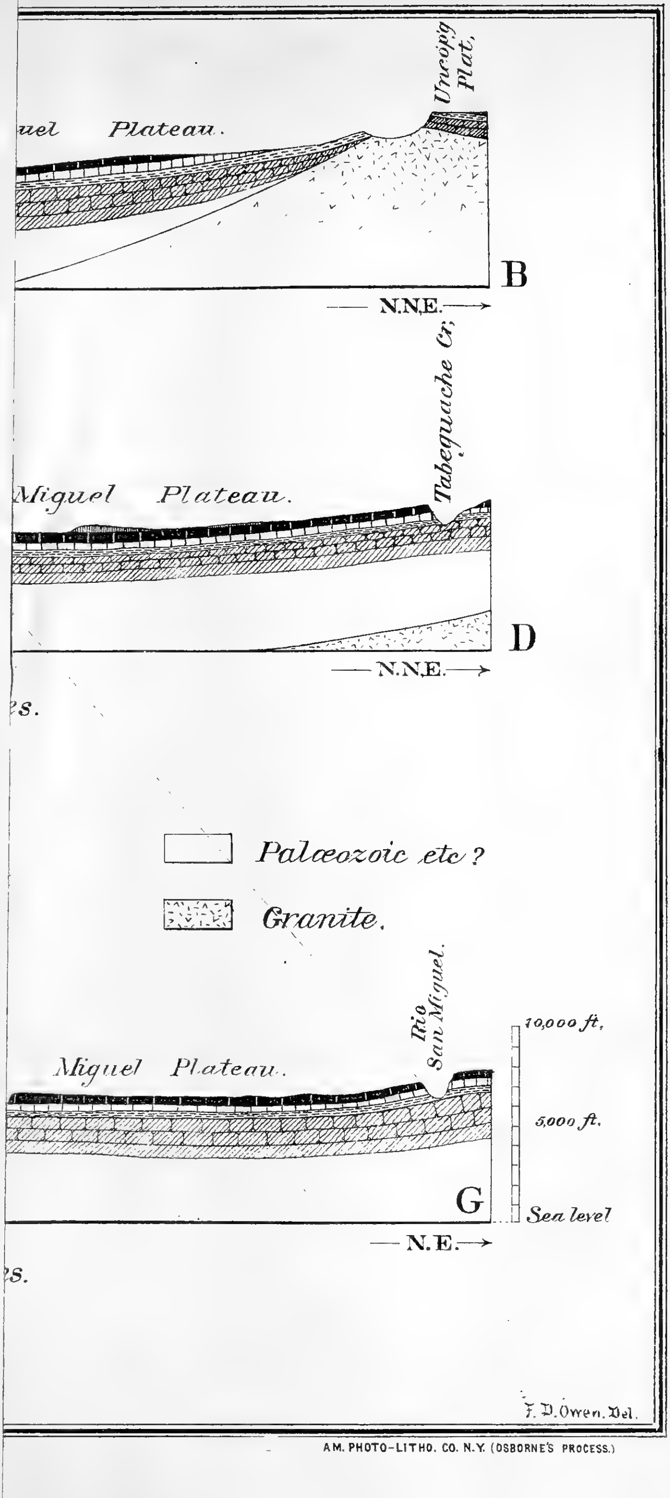
BASIN PLATEAU.

From the northeastern edge of Gypsum Valley the Dakota sandstones dip gently to the northeast, and become almost horizontal in the centre of Basin Plateau, and beyond rise in a low ridge through which Basin Creek cuts a deep cañon. The centre of Basin Plateau is floored with the lower portion of the Colorado Cretaceous, remnants of the strata that form mesas farther south. Toward the northwest the Dakota sandstones form the surface, extending eastward to the southwest edge of Paradox Valley. The ridge through which Basin Creek cuts its way out of the plateau begins in the southeast as a very gentle fold. Its culmination appears to be at the cañon of Basin Creek. (See sections, plate No. IX.) The red beds are exposed in the centre. The western side of the anticlinal diminishes in inclination as we trace it toward the northwest, where it forms the wall of Paradox Valley. The eastern side of the fold, as we trace it, is seen curving to the eastward, forming the rim of a dish-like depression. On the east side of this is a line of faulting which fades out into a fold to the southeast. The axis of this fold is parallel to that next west, but the fold is much gentler, and soon dies out in San Miguel Plateau. The sections in Plate No. IX will give a clearer idea of this folding.

PARADOX VALLEY.

About four miles above the mouth of the San Miguel River the Rio Dolores is seen cutting its way from a broad valley through a bluff wall some 1,600 feet in height. The valley is about three miles in width, and the river comes into it from a cañon on the west which is almost as deep as the one by which it makes its escape. This valley, which stretches

Plate IX.



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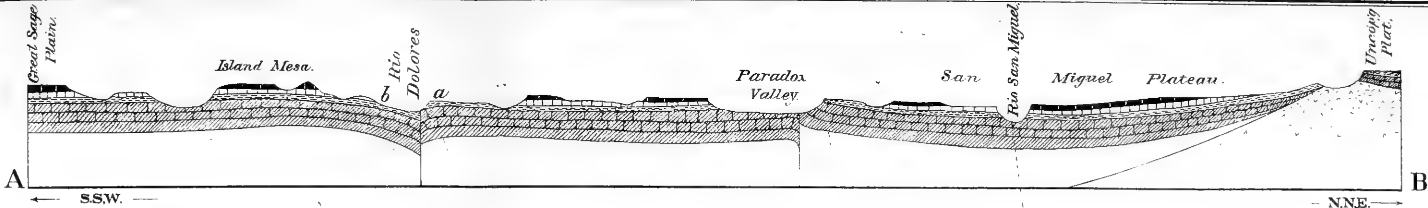


Fig. 1. Section on line A.B. of Map. Plate 8. 39 miles.

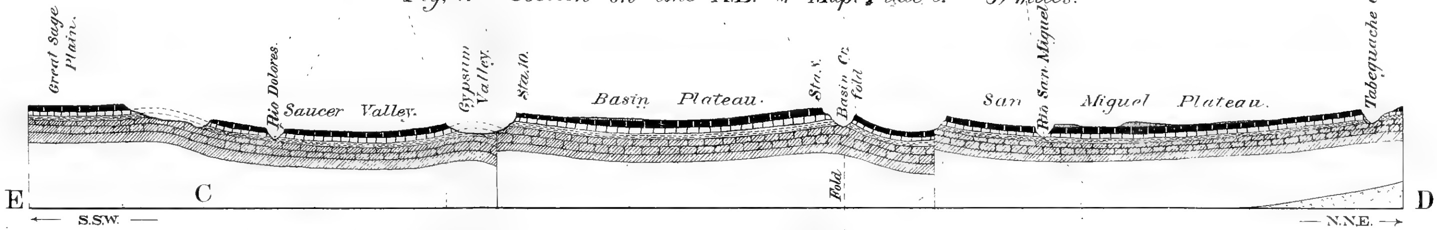


Fig. 2. Section on line C.D. of Map. Plate 8. 39 miles.

Upper Dakota. | Lower " . | Variegated Beds. | Red–Beds. | Palæozoic etc ? | Granite.

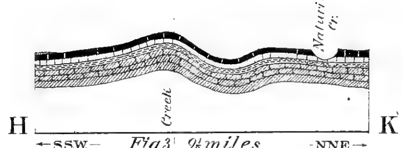


Fig.3. 9½ miles
Section on line H.K.

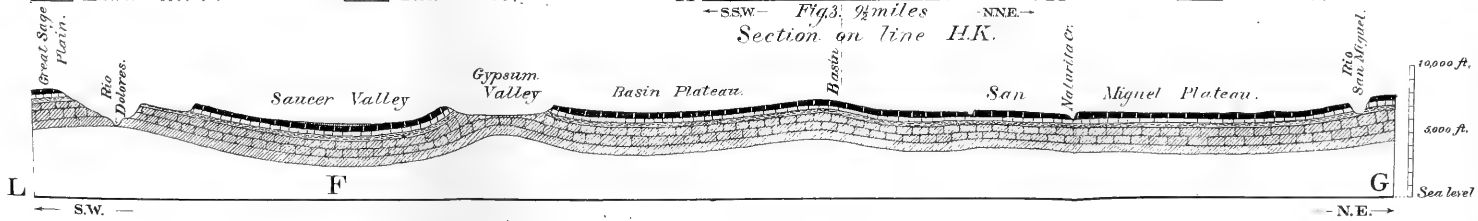
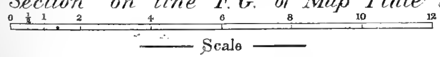


Fig. 4. Section on line F.G. of Map Plate 8. 39 miles.



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to the northwest and southeast at right angles to the course of the river, has been named Paradox Valley. The beds on both sides of the valley present their basset edges toward the axis of the valley and dip gently away from it to the southwest and to the northeast. It would appear, therefore, to be a simple anticlinal axis with the centre removed. The erosion of the strata has greatly obscured the relations of the different beds. The bluffs on the southwest are lower than those on the northeast, and show no beds lower than the Jurassic variegated shales, while the opposite ones show a considerable thickness of the underlying red sandstones and shales that we have been accustomed to refer to the Trias. If, therefore, this valley be a simple anticlinal, it must occupy a position west of the axis. I am inclined to believe that it—the fold—is not simple, but analogous to that of Gypsum Valley, *i. e.*, there is a fold with a fault to the eastward, along the foot of the bluffs on that side. Crossing to the southeast to the synclinal basin on Basin Creek, we find evidences of faulting on a direct line with the bluffs. The fault of the west side of Sindbad's Valley (see p. 63, Report U. S. Geol. Survey for 1875) is also on the same line. The prevailing formation in the valley is the Trias? covered in most places with drift. The latter increases toward the north. The bluffs on the northeast, as we go north, are in two steps, the upper being of Dakota sandstone, which slopes to the San Miguel River. The lower step has Jurassic shales capping the red sandstone. North of the Dolores, the Red Beds prevail and Upper Carboniferous beds outcrop at the base of the cliffs. Owing to the limited time, this portion of the valley was not visited.

SAN MIGUEL PLATEAU.

The San Miguel Plateau calls simply for a mention here, as the reports for 1875 refer to it so frequently. We crossed it on the trail that leads from the Uncompahgre agency to the Navajo Indian country.

The elevation of the plateau near the mountains is about 8,000 feet, and here pines are found. Near the mouth of the San Miguel the elevation is about 6,000 feet, and the surface covered generally with sage-brush. All the streams are in cañons from 800 to 1,000 feet below the surface, with but little bottom-land. The Dakota sandstones form the surface rock, but that higher beds once prevailed over the entire area is evident from the remnants of Colorado shales that are now found at several localities. The largest area of shales is found between the San Miguel River and Tabeguache Creek, occupying a synclinal depression. The areas of shales are indicated on the map (Plate VIII).

CHAPTER III.

AREA B—GRAND RIVER VALLEY—ROAN OR BOOK CLIFFS—LITTLE BOOK CLIFFS.

As indicated in a previous chapter, Area B includes about 3,000 square miles. Of this, 1,100 represent Grand River Valley. The entire drainage of the area is tributary to Grand River, which forms the southern boundary. The northern boundary is the crest of the Roan or Book Cliffs. Almost all the area is a desert, and can be worked in detail only in the spring or early summer months. It was visited by us in the last week of September and the early part of October, when the streams were dry. Salt Creek was the only one carrying water, and it was a trickling stream of strongly alkaline water. The region between the crest and the foot of the cliffs is also destitute of water except at a few places. To be worked in detail it will have to be visited in the spring; and the crest, along which an Indian trail takes its way, will have to be the line from which it is worked. The cliffs are rugged and precipitous, and considerable time will have to be spent in finding good places to descend. Fortunately the geological structure is so simple that a good idea of the areas occupied by the various formations was obtained during our hasty trip along the crest, and no difficulty was experienced in coloring the geological map. The formations represented are mainly Cretaceous and Tertiary, the outcrops of Jurassic and Triassic being limited to a narrow belt along the course of Grand River.

GRAND RIVER VALLEY.

Following the Uncompahgre River northward, we find the broad valley in which it is located extending northwestward along the Gunnison and becoming the Grand River Valley below the mouth of the Gunnison. It keeps a northwesterly course as far as Salt Creek. It then curves around to the southwest, following the course of Grand River, which curves around the northern end of the Uncompahgre Plateau. Beyond Muddy Creek the valley extends westward toward Green River. The total length of the valley following the general course of the river is about 75 miles. Its width opposite the mouth of the Gunnison is 9 miles. On Salt Creek it is 15 miles, and on Muddy Creek about 20 miles. The valley is nearly flat, there being a slight slope from the foot of the cliffs toward the river, and a still smaller slope toward the cliffs from the edge of the low hogback ridge bordering the river. A line of stations was made on this ridge. The valley is for the most part a desert, covered with a sparse growth of stunted sage-brush, which grows in a stiff alkaline soil made from the débris that is washed from the Book Cliffs. Along Grand River in the bottom-land there are groves of cottonwood. A portion of the valley between the Little Book Cliffs and Salt Creek may be reclaimed by irrigation from Grand River. Beyond Salt Creek the level is too high above that of the river, which is in cañon, to be available for agricultural purposes by irrigation. West of Muddy Creek the country rises into the divide between Grand and Green Rivers. The streams flowing from the cliffs to Grand River have cut deep

arroyas or gullies in the soft soil. Salt Creek was the only one that carried any water when we crossed them. Desert Creek had a small stream at the edge of the valley close to the foot of the cliffs, but the water, which was alkaline, soon disappeared. The formation forming the floor of the valley is the Middle Cretaceous or Colorado group, the dip of the beds being away from the river.

Between the mouth of the Gunnison and Station 4 a wide alkali flat extends from the foot of the Little Book Cliffs to Grand River. The latter stream comes from a deep cañon (named Hogback Cañon) cut through the Little Book Cliffs, and flows almost directly west across Grand River Valley nearly at right angles to its course. On the south side of the river, the shales of the Colorado group are seen dipping 2° or 3° in the bluff, which is about 200 feet high.

After the Gunnison joins the Grand the latter takes the course followed by the former above its mouth, and hugs the lower or southern side of the valley. South of the river is a low hogback ridge of Dakota sandstones, dipping toward the northeast. On these sandstones rest remnants of the shales. The Dakota group crosses to the north side southwest of Station 4, at the point where the wagon-road leaves the river, and soon rises into a ridge of about 300 feet, on which Station 5 was located.

Station 4 was on a remnant of a former level of the valley, a yellow-topped butte underlaid by black argillaceous shales (probably Cretaceous No. 2).

Station No. 5 was on the edge of the cañon of the Grand. The river is in the upper part of the Red Beds, above which is the following section:

Base.	Feet.
1. White sandstones with thin bands of limestone } 2. Greenish shales }	80
3. White sandstones	71
4. Variegated shales and marls reddish and greenish	70
5. Yellowish white sandstone, rather massive	88
	309

The thicknesses were measured by angles, taken with the gradienter.

Layers Nos. 4 and 5, and perhaps No. 3, belong to the Dakota group, while the remainder of the section is referable to the Jurassic, the decrease in thickness from that in the southern area being probably due to the presence in this region of limestones.

Station 6 was located on a mesa of Dakota sandstones. The dip here is not great, although it increases a little as we go north from the station, and the sandstones disappear beneath the Colorado shales. Salt Creek flows into the Grand at the head of the bend. From this bend to Station 8 the river is in a narrow cañon cut in the Red Beds. These are seen on the south side of the river rising to the south in the Uncompahgre Plateau. Opposite Station 7 several buttes are seen which have cappings of Jurassic shales. On the north side of the river the Jurassic forms most of the surface, although there is one area between Stations 7 and 8 where it has been removed. The following section was obtained here:

Top.	Feet.
1. Massive sandstone, general color light red, white on top	150
2. Red laminated sandstones and shales	100
3. Massive sandstone, deep red in places and light red in others	200
	450

On the south side of the river the upper layers appear to have been eroded away, not showing until the mesas, five or six miles south of the river, are reached.

The cañon of the Grand appears to be impassable, and the road makes a detour around it. It is thirty miles from where the road leaves the river, above Station 5, to the point where it touches it again, below Station 8. The gullies crossed in this distance are all dry, with the exception of Salt Creek, the water of which is alkaline. Although dry, these gullies are deep, especially between Stations 7 and 8.

The following is the section at Station 8:

Top.	
1. Massive yellowish sandstones with faint impressions of stems	250 feet. (1–2)
2. White marls and reddish sandstones	
3. Dark-colored hard sandstones, with a layer at the base containing nodules of jasper	
4. Variegated marls	260 feet. (3–5)
5. Greenish marls and sandstones with thin bands of limestone at the base	
6. Massive red sandstones (top of Trias?)	
Total	510 feet.

It is difficult here, as at the other localities, to draw the line between the base of the Dakota group and the top of the Jurassic.

Between Station 7 and Station 8 is a kind of basin of Jurassic shales, the stations being located on two points or tongues of the Dakota sandstone. North of the hogback ridge of Dakota sandstone the shales form low bluffs, and between these and the foot of the Book Cliffs the surface is diversified by buttes and mesas eroded from the shales. The Dakota sandstones dip toward the northwest 3°–5°.

Bitter Water Creek joins the Grand below Station 8; and just below the mouth of the creek, the river enters a cañon in the Red Beds. This cañon is 500 or 600 feet in depth at its head, and this probably increases as the river is followed.

From the head of the cañon to the Horse-shoe Bend, the Red Beds outcrop on both sides of the river. Station 9 was located on a Jurassic-capped butte on the north, or rather west side of the river, for the Grand here is flowing but a few degrees west of south. On the east side its tributaries cut profound cañons in the Red Beds, and at their sources may even expose the underlying granitic rocks.

At Horse-shoe Bend the valley becomes more open, and below the bend the river flows from the Red Beds into the Jurassic shales. Below the mouth of Granite Creek the Grand makes a right-angled bend and flows to the southwest, cutting across the hogback ridge into a synclinal basin of Cretaceous shales. The strike of the Dakota group is at right angles to the course of the river, and just above the mouth of the Rio Dolores we find the Grand again cutting across the Dakota group at right angles to its strike. The synclinal depression between the Dolores, Granite Creek, and Grand River is the result of two folds meeting, viz: that of the northern end of the Uncompahgre Plateau, and the fold that marks the western edge of the same plateau farther south. This latter fold, with its axis slightly changed (*i. e.*, more to the westward), continues from the Grand to Green River. A line of hogbacks, capped with the Dakota sandstones, is seen stretching to the westward

from the Grand at the mouth of Muddy Creek. South of this is the Dome Plateau, named from the domed shape of the country.

From the foot of the hogbacks there is a gradual swell, covered for some distance with a portion of the Jurassic. This, however, soon disappears, and the upper part of the Trias (?) forms the surface, reaching to the edge of the cliffs overlooking the *Valle Colorado* of Grand River. A section of the beds in these cliffs at station 12 was given in the Report for 1875, p. 83.

In the western part of Grand River Valley there are three streams, Muddy, Alkali, and Desert Creeks, rising in the Book Cliffs. The names were given as an indication of the kind of country through which they flow.

Muddy Creek rises in the cliffs outside of the district. Like the others in Grand River Valley, the course of this stream can be traced by the line of sage-brush along its gulley. In the cliffs it probably has running water, and near its mouth we saw several pools of alkaline water.

Alkali Creek we found entirely destitute of water, and it is probably only in the spring that it is a running stream. The bed of Desert Creek contained a trickling stream at the entrance to the cliffs, but it soon disappeared in the clayey deposits of the valley. On the way across the valley to the exit of Desert Creek, we crossed a low mesa about half way from the Grand to the cliffs. This mesa, not a hundred feet high, is capped with a sandstone which had a dip of 1° or 2° toward the cliffs.

Grand River Valley is a valley of erosion determined first, perhaps, by the fold resulting from the upheaval of the Uncompahgre Plateau. An immense amount of material must have been removed to form the trough that we now see extending along the Uncompahgre, Gunnison, and Grand Rivers to the Green. We leave the Grand just as it enters the great cañon-country so characteristic of the great Colorado River of the West.

As has already been stated, the valley is not adapted for agricultural purposes, and much less for grazing, unless there should be a change of climate. Traces of a poor quality of coal are found at several places in the sandstones at the summit of the hogbacks along the Grand, but it is of no economic importance. Gypsum is found in the Jurassic shales, and also in the Colorado Cretaceous, but as far as seen, not in beds, nor as large deposits.

ROAN OR BOOK CLIFFS.

The cliffs that overlook the Grand River Valley are divided into two portions, the Roan or Book Cliffs, overlooking the western part, and the Little Book Cliffs, overlooking the eastern part, extending from Hogback Cañon of Grand River to Salt Creek. The name Roan is given on account of the color, and the name Book Cliffs from the resemblance of their edges to those of a bound book. The summit of the cliffs forms the southern edge of the Roan or Book Plateau, which extends northward, forming the district investigated by Dr. Endlich. In this direction the streams flow in the direction of the dip of the rocks, and the country is not so rugged as that on the south. North of the bend of Grand River is the basin drained by Salt Creek, which has its sources about 16 or 18 miles north of the northern edge of Grand River Valley, while the other streams have a much shorter course in the cliffs. The edge of the cliffs is the divide between the drainage of Grand River and that which flows to White River. From Bitter-water Creek this divide has a nearly due east and west direction until the head of the first

branch of West Salt Creek is reached, when an abrupt turn to the northeast is made. At the head of West Salt Creek the course is somewhat winding between the branches of that creek and those of the White River streams. The plateau character so noticeable farther west is lost here. The general direction of the divide is east and west to the head of Roan Creek. East of Roan Creek the plateau character again prevails, especially along Grand River, as shown in Fig. 2, Plate X (a sketch of the cliffs and plateau on the north side of the Grand from Roan Creek to Cactus Valley, made by Mr. Holmes). The dip of the strata here is to the northward. Between Salt Creek, Roan Creek, and the Little Book Cliffs the country is considerably broken up. The drainage is generally to the east, and remnants of the plateau are left as long tongue-like mesas between the branches of Roan Creek.

The surface rocks on the plateaus everywhere throughout this region are the white shales of the Green River group of Tertiary. Between Desert Creek and Bitter-water Creek, the summit of the cliffs is about 12 miles from the edge of Green River Valley. The intervening country is very rugged. Spurs extend southward from the cliffs between the streams. These spurs are composed mainly of Wahsatch beds, which, toward the west, are composed of sandstones, generally white in color, but with layers of a pink color.

We reached the summit of the cliffs by following an old and rough Indian trail that led up Desert Creek. This part of the cliffs was outside of the district, but it presented the only means of access to the plateau, which here is 3,787 feet above the valley. At the entrance of the creek to the valley there are low hogbacks, in which the beds dip about 6° toward the cliffs. The general dip appears to be a little east of north, and this becomes more easterly as we follow the cliffs to the westward.

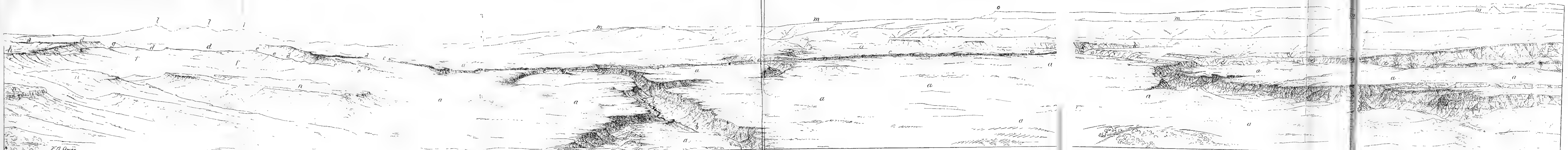
The following section was made at the exit of Desert Creek, the thickness being estimated:

Section.

	Base.	Feet.
Colorado ...	1. Colorado shales about	200
Fox Hills ...	2. Sandstone	75
	3. Shales with lignite band	300
	4. Sandstone	50
	5. Shales	100
	6. Sandstones	25
	7. Shales with lignite band	75
	8. Sandstones	25
Laramie ? ...	9. Massive sandstones with thin bands of shales	600
Wahsatch ? .	10. Heavy bands of white and yellowish sandstones with interlaminated red and reddish shales and sandstones	4,000
Green River	11. Greenish laminated shales and white sandstones and shales.	

Bed 1 represents only a portion of the Colorado group.

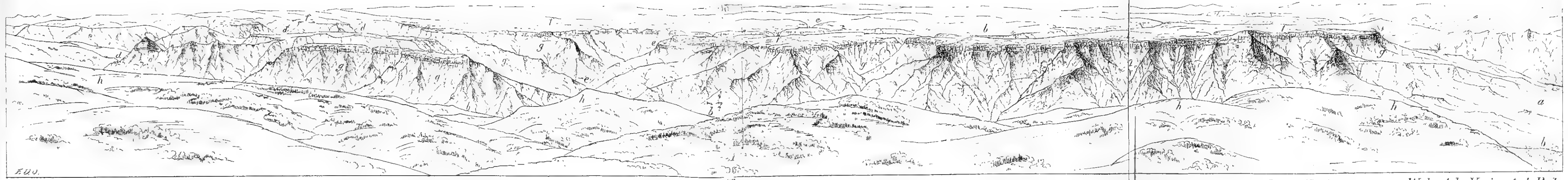
The sandstones 2 and 4 form escarpments facing the valley. As No. 4 is traced up the creek, it is seen to thin out as it sinks into the hills beneath the upper beds. Instead of one band of sandstone there are several, and the line between 4 and 5 becomes very indefinite. This we find to be the case very frequently in this region. A band of sandstone may be very persistent for a long distance, and then split into several layers and perhaps disappear. The line between the Laramie group and the Fox Hills is especially indistinct. The time at our disposal did not permit of careful search for fossils.



a, a, a, San Miguel Plateau. b, b, b, Naturita Creek. c, c, c, Rio San Miguel. d, d, d, Rio Dolores. e, e, e, Paradox Valley. f, f, f, Basin Plateau. g, g, g, Gypsum Valley. h, h, h, Saucer Valley. i, i, i, Island Mesa. k, k, k, Muache Creek. l, l, l, Sierra la Sal. m, m, m, Uncompahgre Plateau. n, n, n, Mesas of Colorado Shales. o, Grand Mesa.

VIEW OF THE SAN MIGUEL PLATEAU FROM LONE CONE.

FIG. 1.



a, a, a, West end of Cactus Valley. b, b, b, Valley of Grand River. c, White Mountain. d, d, d, Cañon of Roan Creek. e, e, e, Cañon of Parachute Creek. f, f, f, Roan Plateau capped with Green River Tertiary. g, g, g, Wahsatch Variegated Beds. h, h, h, Northern Spurs from Battlement Mesa.

VIEW OF THE ROAN OR BOOK CLIFFS ON GRAND RIVER

FIG 2.

a, a, a, a, a, Colorado Shales, Cretaceous. b, b, b, b, Fox Hills, Cretaceous. c, c, c, Laramie, Post Cretaceous.

VIEW OF THE LITTLE BOOK CLIFFS

FIG. 3

marked No. 11 are undoubtedly the Green River group of y, as fossils were obtained from the beds farther east. The them and the Wahsatch (No. 10 of the section) cannot be rawn in the western part of the cliffs, as the variegated charac- Vahsatch group noticed farther east is here almost lost.

n 19 the summit is 3,400 feet above the valley. Between and 21, the plateau character is well preserved. The streams do not cañon very rapidly and the angle of dip in the strata 4°. Grass and sage-brush grow everywhere on the plateau. verlooking Grand River Valley are composed of sandstones minated greenish shales with spurs projecting southward like faces on the west side, while the eastern slopes are more l grassed over.

head of the creek, flowing northwest from Station 21, a num- altum springs were found. They are really in the district Dr. Endlich's party, but as they were visited by us, I insert ion: These springs are found in two cañons, marked *a* and area B (Plate XI). On the north side of cañon *a* a space t square is covered with the hardened asphaltum, and a line material leads to the crevice above, from which it came. it early on a cool morning and no flow was noticed. Near however, the tar was soft. On the opposite side of the cañon ot was noticed, and farther down the cañon four or five more. um appeared to come from under a steel-gray sandstone, ich is an oolitic limestone. In some places the latter ap- clude irregular masses of limestone. Cañon *b* was tributary the east side contained an area of about 50 square feet on ardened asphaltum formed the surface. Several points were re it oozed from the side of the cañon, but the rocks were posed. It, however, is at about the same level as those in ñon.

hur springs were noted in connection with the asphaltum. first detected by their odor. The water flowing over the ed it with sulphur. An oily substance was noted on the he water. The temperatures were 45° F. and 47° F., while at 55° F. The time was 9 a. m. The discovery of these due to Mr. J. E. Mushback, of our party. Others of the he same region probably have similar springs, and Dr. es the occurrence of asphaltum farther north, which is prob- ted in some way with this locality. The subject will be dis- s report.

Stations 21 and 23 the divide is narrow, in some places ly room enough for the trail. The cañons on both sides are is often difficult to find a way of descent. An oolitic lime- nd all along the divide, and also fine green shales, that are gillaceous.

ter Fork appears to occupy a slight synclinal depression f Station 23. On the west side of the stream there is a dip north, and on the east side the beds dip a few degrees north

n lying between Stations 25 and 26 and the edge of Grand y was not visited, but simply seen from the stations. The r shales continue to form the surface-rocks on the highest the variegated Wahsatch beds showing in the cañons.

ing Grand River Valley, we find the sandstones of the

Laramie group appearing, and below them the shales and of the Fox Hills Cretaceous.

We left the plateau at the head of Roan Creek, and f stream to Grand River. Where we descended, the cliffs 1,400 feet high. This is just east of Station 27. The strat horizontal, and belong to the Green River group. A sh down the stream we reached the Wahsatch beds, which outcrop along the creek almost to its mouth. The variegat of these beds is very marked in this region.

There are slight evidences of an anticlinal fold in the Wa in the bottom of the valley. In the cliffs the Green Riv pears to be horizontal, and there must therefore be either an ability between the two groups or erosion has removed tha the Green River group which was affected by the fold. Er obscured the beds in the valley that it is difficult to determi conditions. That there was a fold I think is evident, and hills bordering the creek on the upper part of its course, fo anticlinal, the creek occupying the axis of the fold. This f determined the course of the creek. As we go down the str appears to die out.

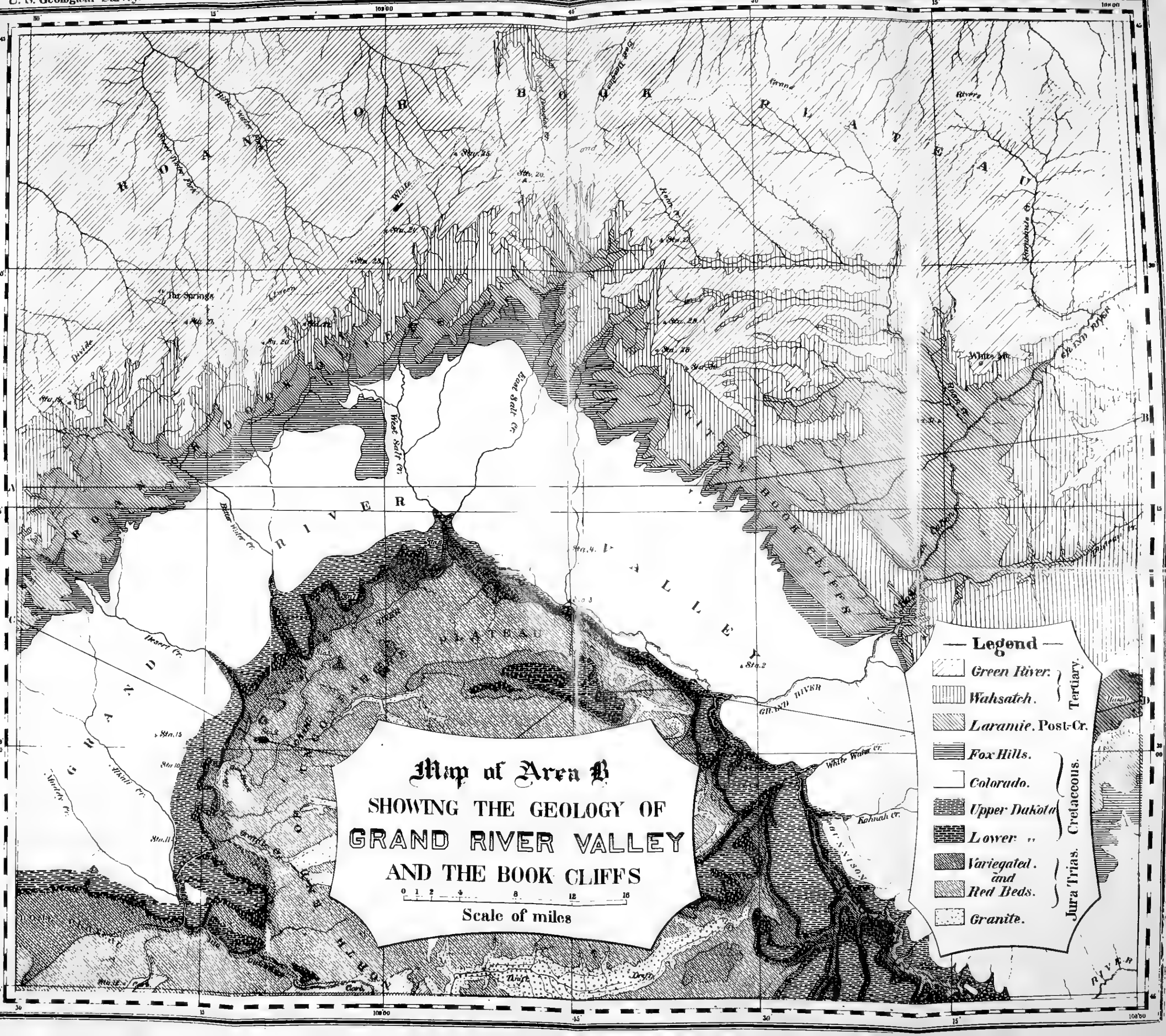
As we approach Grand River a series of massive and lam stones appears beneath the Wahsatch group. South of W ain these sandstones form bluffs of 400 to 500 feet facin They probably represent the upper part of the Laramie grou ing up the river these sandstones soon disappear, and t Wahsatch beds also sink for a short distance, but soon rise continue almost horizontal. What dip there is appears the north. The white and yellow beds of the Green Rive cliffs at the summit of the bluff, while the underlying soft beds weather in their characteristic slopes. This is well sl 2, Plate X (a sketch of the Roan Cliffs on Grand River, Holmes).

Between Parachute Creek and Cactus Valley the Wahsat the characteristic weathering of Bad Lands into columns Along the river there are well-marked terraces cut in the so the south side these terraces are covered with bowlders o have been washed from the Battlement mesa. I did not n the north side. The steepness of the cliffs on the north sid deep gullies to be cut by the small branches of the Gran on the south side are more rounded, and the stream-beds r depth.

In Cactus Valley we found the variegated beds formin facing the river, and low hogbacks inclining from the Gra Range. This, however, lies in Dr. Endlich's district, described by him. The only portion of the district rema described is the Little Book Cliffs, through which Gran its hogback cañon from the mouth of Plateau Creek to Valley.

LITTLE BOOK CLIFFS.

The Little Book Cliffs extend from Grand River north East Salt Creek, a distance of some thirty miles. Fig. gives a view of the cliffs as seen from the south side of the cliffs are about 1,800 feet in average height. Near the G lowing is the section (point *c ?* in Fig. 3, Plate X). The th measured by angles taken with the gradienter from a st south side of the Grand.


Map of Area B
SHOWING THE GEOLOGY OF
GRAND RIVER VALLEY
AND THE BOOK CLIFFS
0 1 2 4 8 12 16
Scale of miles
Legend
Green River.
Wahsatch.
Tertiary.
Laramie. Post-Cr.
Fox Hills.
Colorado.
Upper Dakota
Lower "
Cretaceous.
Variegated. and Red Beds.
Jura Trias.
Granite.
ROAN OR BOOK PLATEAU
BOOK CLIFFS
GRAND RIVER VALLEY
GRAND RIVER
East Salt Cr.
West Salt Cr.
The Springs
Divide
White R.
Desert Cr.
White Water Cr.
Kahnah Cr.
GUNNISON
PLATEAU
RIVER

Section.

Base.

		Feet.
Upper part of Colorado Cretaceous.	1. Black and yellow shales, with limestones?	800
Fox Hills Cretaceous.	2. Yellow sandstone, forming an indistinct escarpment 3. Yellow shales and sandstones, with a band of lignite near the upper part	710
Fox Hills Cretaceous.	4. Sandstone 5. Shaly beds	380
Laramie?	6. Pinkish sandstones	
Total		1,890

These beds dip to the northeast at an angle of about 8°. As we trace layer No. 2 toward the northwest along the cliffs it becomes somewhat indistinct. The beds also, as seen from Station 4, appear to sink, and the Laramie sandstones undoubtedly form the escarpment at the summit of the cliffs. Still farther along, the beds rise again.

East of Station 4 and back of the first line of cliffs a second line is noted, in which the beds are the variegated shales and sandstones of the Wahsatch Group. The sketch in Fig. 3, Plate X, is taken from too low a point to show this line of cliffs. As we approach East Salt Creek the Wahsatch beds come to the front, continuing westward from a low range of hills which represent a portion of the Roan Cliffs. They do not remain in front long, but retreat and form the base of a line of cliffs which extend southwest from Station 28. The latter marks the angle of a bend, a line of cliffs extending southeast from the station. Station 30 is located on the same line. These cliffs are capped with Green River Tertiary, and are about a thousand feet higher than the outer cliffs, from which they are distant about six miles.

The map of Area B will enable the reader to obtain a clearer idea of the extent of the cliffs and the areas occupied by the various formations represented in them.

There is room through all this region for much detailed work which the lateness of the season and small amount of time at our disposal prevented us from accomplishing.

CHAPTER IV.

GEOLOGICAL FORMATIONS OF THE GRAND RIVER DISTRICT.

In this chapter I shall endeavor to present in as concise a manner as possible the various facts observed in regard to each formation.

The following list represents those coming under observation during the season:

Upper Carboniferous.
Triassic?
Jurassic.

Cretaceous	Lower Dakota group Upper Dakota group. Colorado group. Fox Hills group.
Post-Cretaceous	—— Laramie group.
Tertiary	Wahsatch group. Green River group.

Post-Tertiary and recent.

On the south side of Grand River (in Area B) there are a few isolated exposures of granitic rock. These were not visited this season, but were referred to in the report for 1875 (p. 66). Neither Silurian nor Devonian was recognized in either district.

Area A is composed almost entirely of Cretaceous strata, while Area B is about equally divided between the Cretaceous and the Tertiary.

UPPER CARBONIFEROUS.

Area A.—A reference to the accompanying map (Plate VIII) will show the areas in which rocks of the Upper Carboniferous formation are exposed. The line separating them from the Trias has been arbitrarily fixed, as the soft sandstones and gypsiferous shales are much like the beds forming the base of the Trias. This is what would naturally be expected when it is remembered that the deposition of the sediments in this region was probably continuous, and the materials entering into their composition derived from the same sources. Both the localities (in Paradox Valley and in the Cañon of the Dolores) noted on the map were seen from a distance, and therefore no details respecting them can be presented. They are probably similar to the rocks of the same age showing farther north and west, which were described in the Report for 1875 (p. 71).

Area B.—The map of this area shows a small outcrop of Upper Carboniferous on Grand River below the mouth of the Rio Dolores. It is unimportant, and was referred to in the Report for 1875.

JURA-TRIAS.

The line separating the Triassic from the Jurassic is almost as obscure as that separating the Carboniferous from the Triassic. The line has

been drawn lithologically, the massive red sandstone being considered the top of the Triassic. The conflicting evidence presented by the organic remains found in the Jurassic and Triassic beds of the West has been referred to in previous reports (1874 and 1875).

Area A.—Hardly more than 60 square miles of the area are covered with the red sandstones of the Trias. A massive red sandstone, becoming lighter colored toward the top, cross stratified at many places, is the prevailing characteristic rock. Its thickness is from 500 to 1,000 feet. The beds become lanimated below, and gypsiferous, passing gradually into the Upper Carboniferous. The variegated sandstone shales that lie above, have been colored on the map to represent the Jurassic. The general character is the same as previously described—soft greenish and gray argillaceous and arenaceous shales and marls near the top, passing into the Lower Dakota sandstone, and dull, reddish laminated sandstones and shales at the base. The limestones that occur farther north near the base appear to be absent here. The area occupied is about 80 square miles. The Rio San Miguel has an outcrop of Jurassic at the bottom of its cañon walls almost its entire length. A few of its tributaries also cut deep enough to expose the Jura. The mesa northeast of Paradox Valley is capped with the reddish shales that lie at the base of the formation. This is also the case with the region included in the bend of the Dolores north of Island Mesa. The streams tributary to the Dolores here cut into the Red Beds beneath. All about Island Mesa, Jurassic rocks are exposed, and the débris filling Gypsum Valley is from rocks of the same age. The structure of this region was described in Chapter II, and a study of the map and sections will make the description more intelligible.

Area B.—In Area B the Trias and Jura are found only along Grand River, the former principally on the south side, and the latter on the north. The lithological line separating them is much better defined than it is in Area A. The sandstones forming the upper part of the Red Beds are very massive, and the shaly beds just above contain thin layers of limestone. Below the massive sandstones come blood-red shales, followed by massive sandstones, generally of a deep-red color, although in many places the color fades to almost white. The thickness exposed is nearly 500 feet, which represents only a portion of the formation.

In the Red and Variegated Beds the Grand cuts a cañon of varying height, but at no place does it exceed 1,000 feet.

The general section of the beds referred to the Jurassic is about as follows:

Base.	Feet.
1. White bands of sandstone with greenish marls and a few thin layers of cherty limestone at the base	80
2. Variegated green and red sandstone shales and marls } 3. White sandstone }	120
Total	200

The variegated character of the shales and marls is much more marked at some localities than at others. At Station 10, near Horseshoe Bend of the Grand, they are rather brilliant in color, and gypsum seems to enter largely into their composition. From Alkali Creek to the Bend the Jurassic beds are seen as remnants capping isolated areas, and on the Dome Plateau the lower portion of the same formation covers a considerable area south of the hogbacks that border the Grand River Valley at this place. A reference to the map of Area B will give the best idea of the extent of the formation.

The line separating the Jurassic from the overlying Dakota is indefinite. The discussion in regard to it will be found in the reports for 1875.

CRETACEOUS.

Area A.—Of the 1,000 square miles included in the area, about 850 are covered with rocks of Cretaceous age. Of this 850 square miles, about 70 have the Colorado group as the surface formation, the rest being mainly Dakota Group.

The Dakota group for the most part is horizontal, and the conditions of the strata are very uniform. It forms the tops of the bluffs on all the cañons. It is a moderately compact, yellowish, silicious sandstone. Beneath are greenish shales and bands of sandstone. The latter have been referred to the Lower Dakota. The total thickness is about 600 or 700 feet, about 200 feet being referable to the upper Dakota.

The massive sandstone at the top in most places appears to have formed a barrier to erosion, the overlying shales having been swept away. Remnants are still seen in Basin Plateau, and in the angle of the San Miguel opposite the mouth of Naturita Creek. Farther south, however, near the slopes of Lone Cone, the shales are more persistent, forming mesas extending northward. The eruption of the trachytic masses seems to have had some influence in protecting them in this locality. These remarks are merely intended to supplement the Report for 1875.

Area B.—As already stated, the whole of Grand River Valley, and a considerable portion of the cliffs bordering it, are occupied by beds of Cretaceous age. Of this, the Colorado shales occupy over 1,000 square miles in the space between the cliffs and the hogbacks on Grand River. They are so eroded and covered by débris that but little can be predicated of them. They form low bluffs back of the hogbacks. The total thickness of the group is about 1,500 feet. The beds consist of calcareous and argillaceous shales with sandstone and limestone bands.

The sandstone of the Dakota group here, as at so many other localities, seems to have presented a decided resistance to erosion, and as a result we find it forming the summit of the hogbacks.

It is somewhat difficult to determine the exact thickness of the Dakota group, as we do not know exactly what its lower limit is. We find the same difficulty in dividing the Dakota Cretaceous from the Jurassic that is always found where the deposition of sediments has been continuous from age to age.

The following is the average section of the Dakota group in the hogbacks on Grand River:

Top.	Thickness in feet.
1. Massive yellow, siliceous sandstone, with faint impressions of dicotyledonous stems, at some localities. 2. Variegated marls, with bands of reddish sandstones. These beds have the characteristic weathering of Bad Lands	90–200
3. Dark-colored sandstones, with bands of marls and shales. Near the base is a layer containing nodules in which there are jaspers	50–100
Total thickness	140–300

The greatest thickness is noted as we go to the southwest, beyond the bend of the Grand.

Bed No. 3, and a portion of No. 2, I have called the Lower Dakota, the name suggested by Mr. Holmes. (Report 1875, p. 261; see also p. 88 of same report.)

Above the Colorado shales, in the Book Cliffs, is a bed of sandstone that forms a well marked escarpment. This bed probably represents the base of the Fox Hills group. Above it are shales and sandstones as follows:

	Feet.
1. Sandstones and shales	650
2. Massive sandstones, with a few bands of shaly sandstones	600

I am inclined to consider a part, if not the whole, of layer No. 2 as belonging to the Laramie group; but, as already stated, the line between the two formations cannot be definitely drawn in the absence of fossils.

In the Little Book Cliffs the sandstones and shales referable to the Fox Hills group are about 1,000 feet in thickness. (See section p. 177, Chap. III.)

Professor White had good exposures of the Fox Hills group farther north, and to his reports the reader is referred for details, especially those of a paleontological nature. At no point in the district did I obtain any fossils from its strata.

POST-CRETACEOUS.

Dr. Hayden first pointed out the transitional character of the sandstones that lie between the marine beds of the Cretaceous and the freshwater beds of the Tertiary.* The paleontological evidence has been conflicting, those studying the fossil flora differing from vertebrate paleontologists. As Dr. White has ably shown in his comparison of the Cenozoic and Mesozoic groups, the testimony of invertebrate paleontology but confirms the position of Dr. Hayden.† For these transitional beds Dr. White has proposed the name Post-Cretaceous. The beds of the Laramie group are the ones so designated. They consist mainly of sandstones.

In *Area A* no beds of Post-Cretaceous age were noted; so I pass to

Area B.—In the western part of this district there is no distinct lithological line separating the Laramie group from the Fox Hills below nor from the Wahsatch beds above. In passing up through the sandstones, it is noticed that they have a tendency to separate into massive bands, between which reddish shales or laminated sandstones appear. As we ascend still higher, they pass insensibly into the shales of the Green River Group.

On Grand River, near the mouth of Roan Creek, there are bluffs in which about 500 feet of sandstones outcrop. These sandstones are probably the upper part of the Laramie group, the variegated beds just above representing the Wahsatch group.

In the Grand Hogback Range, just east of Cactus Valley, the following fossil plants were obtained, the identification being by Professor Lesquereux:

Ficus auriculata, Lesqx.
Ficus planicostata, Lesqx.
Ficus planicostata var. *Goldiana*, Lesqx.
Diospiros crassinervis, Lesqx.
Salix ——?
Cinnamomum, fragment.

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* Report U. S. Geol. Survey, 1870, pp. 165-166.
†Bulletin No. 3, vol. iii, pp. 624-629.

In a letter, Professor Lesquereux says "all" these leaves "are characteristic of the Lower Lignitic or of the Lower Eocene, and have been found at Point of Rocks, Black Butte, and Golden, especially, the most abundant fragment being of *Ficus planicostata*, and its variety *Goldiana*. These plants were obtained from a sandstone at the very top of the group which I have referred to, the Laramie group; and this bed may perhaps be referred in the future to the Wahsatch group.

TERTIARY.

The Tertiary strata cover larger proportionate areas in the northern district (Area B) than any other. The accompanying map (Plate XI) will give the best idea of their extent. In Area A there are no beds referable to the Tertiary.

The Tertiary strata capping the Book Cliffs extend northward into Dr. Endlich and Dr. White's districts, dipping gently away from the edge of the cliffs. The Green River group forms the summit as an escarpment, in which the beds weather of a white color, from which the variegated beds beneath are distinctly separable in the eastern portion of the area. Toward the west, however, the distinction is not well marked, as the Wahsatch beds consist of harder sandstones and the variegated character is almost entirely lost.

The following table will show at a glance the differences at the different points. The third section was made in 1874, but is in the same neighborhood:

Comparison of Tertiary strata in Northwestern Colorado.

[Area B, near Grand River.]

Western portion of the Roan or Book Cliffs, 1877.		Roan Cliffs on Grand River at White Mountain, 1877.			South side of Battlement mesa on Plateau Creek, 1874.		
Green River.	*Feet.*	*Green River.*	*Feet.*	*Feet.*	*Green River.*	*Feet.*	*Feet.*
Greenish laminated shales and white indurated argillaceous shales		Yellowish beds, limestones and shales forming the escarpment at the top of the cliffs	682		Indurated clays and greenish shales	1,000	
Wahsatch.	3,600	White indurated calcareous and argillaceous shales, with bands of sandstones	1,300		Soft and hard sandstones and greenish shales	1,600	
Massive sandstones separated by bands of laminated reddish sandstone and sandstone shales		Sandstones and shales	300	2,282	Massive sandstones and greenish argillaceous shales	581	3,181
		Wahsatch.			*Wahsatch.*		
		Soft, variegated (red, yellow, and green) marls and sandstone shales. These beds are gypsiferous and calcareous. Near the base bands of sandstone are noticed	......	1,650	White, red, and yellow gypsiferous sandstones and marls. Sandstone. Red, gray, green, and orange marls and sandstone shales. Black, green, and bluish marls	......	2,600
Total thickness	3,600	Total thickness	......	3,932	Total thickness	......	5,781
Laramie.		*Laramie.*			*Laramie.*		
Massive and laminated gray sandstones	1,000	Massive and laminated sandstones	......	500†	Reddish and yellowish-gray massive sandstone	......	330

In the section made at White Mountain the thicknesses were measured by angles taken with the gradienter.

On Plateau Creek the thicknesses are partly estimated and partly measured with an aneroid barometer. This will perhaps account for the discrepancy in the thicknesses, although the beds are probably thicker on Plateau Creek than on Grand River.

WAHSATCH GROUP.

In the western part of Area B the Wahsatch group cannot be definitely separated from the overlying Green River nor from the underlying Laramie. I therefore pass to the eastern portion of the district.

A belt of Wahsatch beds extends from Grand River up Roan Creek a little above the bend, southeast of Station 27. The creek appears to occupy the axis of an anticlinal fold in the variegated beds. The outcrop becomes thicker as we descend until the entire thickness is exposed. At the top are laminated sandstones and greenish shales. These may be the lower portion of the Green River group. Below are the variegated greenish, yellow, and red marls and shales, separated by bands of laminated sandstone. The latter are not persistent, but often entirely fade out. On Grand River I counted five separate bands, which varied in thickness. At one place they were 50 to 75 feet thick, and a short distance beyond only 5 or 10 feet. Some of these sandstones are pink, others yellow or greenish, in tint. In most places the variegated beds weather into the columns, spires, and other forms so characteristic of *Bad Lands.* These beds are the same that in 1874 were referred to the Green River group, in which was included the Wahsatch group (Report 1874, p. 156). From the beds on Plateau Creek the following vertebrate remains were obtained: *Crocodilus*, *Emys*, *Trionyx*, *Pappichthys.*

In the Cactus Valley, a low mesa extends southward from the Grand Hogback Range east of Rifle Creek. In the bluff, on the east side of this mesa, the following fossil plants were found: *Rhamnus*, species new, *Aralia gracilis.* Of these Professor Lesquereux says: "No. 5 (the number of the specimens) has two species only, a new species of Rhamnus like *R. Goldianus*, Lesqx. (Lower Lignite), but with a somewhat different nervation, more like species of the Lower Miocene of Europe. *Aralia* (*Araliopsis*) *gracilis*, Lesqx., is a very fine species, as yet represented by one specimen only from Bridger Pass. Again he says: "Specimens No. 5 are Upper Eocene?" Similar beds, holding the same stratigraphical relation to the Green River Group as these, outcrop in Dr. White's district. He will discuss the question of their age more at length in connection with the evidence furnished by paleontology.

GREEN RIVER GROUP.

The white shales mark the beds of the Green River group all along the Book Cliffs. They consist of indurated, argillaceous, calcareous, and arenaceous shales. When broken, they are generally dark-colored inside. Toward the west there are layers of green and white fissile shales. At Station 20 the summit of the cliffs is a yellow sandstone, and all along the divide in this neighborhood there is an oolitic limestone that comes in near the summit.

At the Cliff Spring the shales contain fossils in at least two different layers.

The following is the general section:

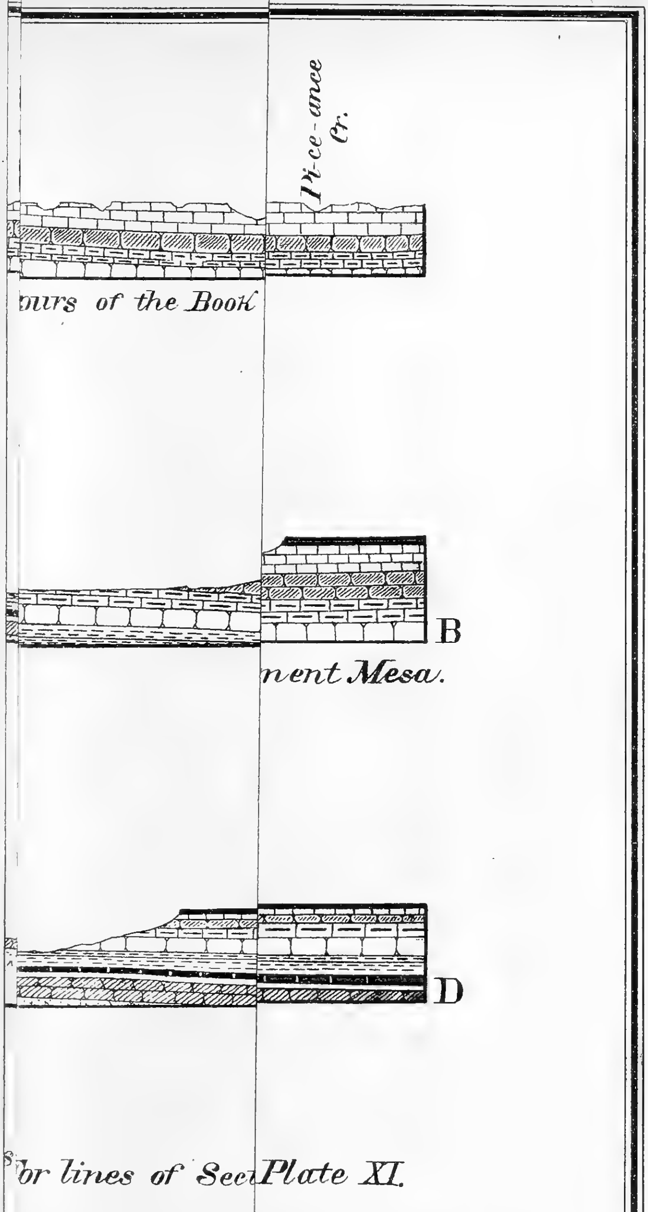
Top.	Feet.
1. Sandstones, limestones, and shales	40
2. Argillaceous shales, dark colored, containing fossils No. 1	} 133
3. Thin white shales, probably calcareous and argillaceous	} 133
4. Dark argillaceous shales, containing fossils No. 2	} 133
5. White arenaceous and argillaceous shales to base of cliff.	

The angle of dip is about 4°, and the inclination is a little east of north.

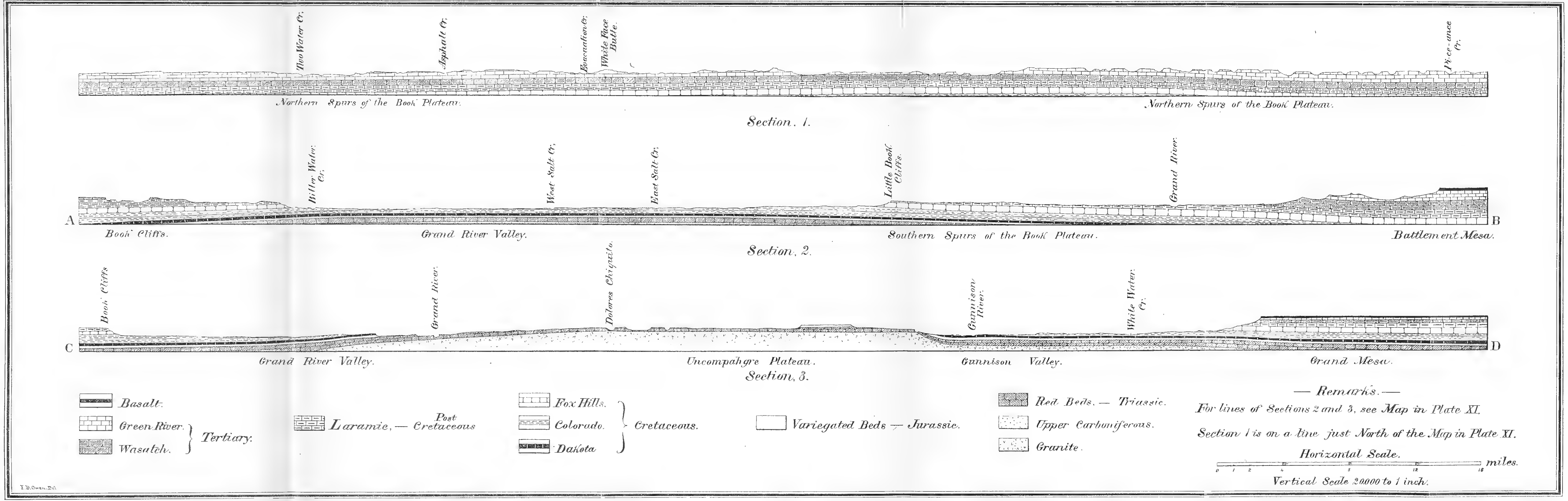
The fossils from layer 2 are—

Planera Ungeri, Heer.
Planera longifolia, Lesqx.

Plate. XII.



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

Myrica latiloba, Heer.
Fraxinus prædicta, Heer.
Myrica acuminata, Ung.
Sapindus angustifolia, Lesqx.
Myrica Copeana, Lesqx.
Spicifer buds of *Equisetum*.
From layer No. 4 the following were obtained:
Planera longifolia.
Spicifer buds of *Equisetum*.

At camp 37, near Station 27, the cliffs were again found to be fossiliferous.

The following is the section:

Top.
1. Limestone, white and crystalline shales.
2. Greenish-gray sandstone with fossils No. 4.
3. Dark argillaceous shales with fossils No. 3. These fossils are about 10 feet below No. 1.
4. White shales to base of cliffs.

Fossils No. 3 are the following:
Myrica latiloba, Heer.
Myrica acuminata, Ung.
Sapindus angustifolia, Lesqx.
Sapindus ——— ?
Ilex affinis, Lesqx.
Stem of *Equisetum*.
Crushed feathers? or hairs.
Fossils No. 4 are—
Myrica latiloba, Heer.
Myrica acuminata, Ung.
Sapindus angustifolia.
Myrica undulata, Lesqx.

For these identifications I am indebted to the kindness of Professor Lesquereux, to whom the specimens were submitted. Professor Lesquereux says: "All the specimens represented from No. 1 to No. 4 show evidently the same formation, that of the Green River group, or Miocene, as it is represented at Elko Station, Middle, and especially South Park, &c. I have specimens of most of the species indicated in your table from the localities here named, Florissant, Castello Ranch, &c. The small cones, spicifer buds of *Equisetum*, are very fine and new."

The following is a general section of the Green River group in the cliffs east of Station 27. It does not include the entire thickness, as a portion of the upper beds has been removed by erosion.

Section.

Top.	Feet.
1. Indurated argillaceous, arenaceous, and calcareous shales, with thin bands of limestone near the top. These shales weather white, but when broken are generally dark inside.	
2. Rusty colored sandstones with interlaminated shales	1,600
3. Thin greenish argillaceous shales, with bands of laminated sandstone	
4. Rusty laminated sandstones	

This thickness was measured with an aneroid barometer. The section at White Mountain is given in the table on p. 183.

It is in bed No. 1, of the section just given, that fossils Nos. 3 and 4 were obtained.

REPORT OF WILLIAM H. HOLMES.

LETTER OF TRANSMITTAL.

OFFICE UNITED STATES GEOLOGICAL
AND GEOGRAPHICAL SURVEY,
Washington, February 1, 1878.

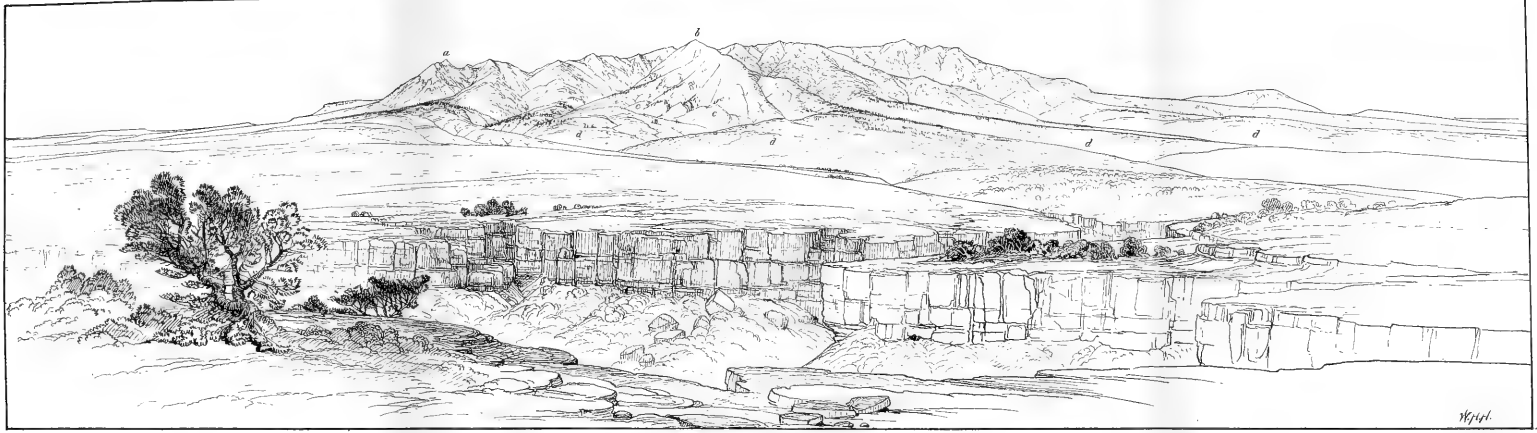
SIR: I have the honor herewith to transmit my report on the geology of the small area examined by me during the season of 1876.

Very respectfully, your obedient servant,

WM. H. HOLMES.

Dr. F. V. HAYDEN,
United States Geologist in charge.

Plate XIII.



a. South-East point-trachyte. b. Abajo Peak, primary station-trachyte. c. c. Hogbacks of Lower Cretaceous Sandstones. d, d, d, Cretaceous Shales. Montezuma Cañon in foreground-Cret. Sandstone.

THE SIERRA ABAJO-FROM THE EAST.

Plate XIII

a. South–East point of Lower Creta

ABAJO-FR

REPORT ON THE GEOLOGY OF THE SIERRA ABAJO AND WEST SAN MIGUEL MOUNTAINS.

By W. H. Holmes.

In the summer of 1876 I accompanied Mr. Wilson, director of the primary triangulation, to the Sierra Abajo or Low Mountains of Southeast Utah. We approached them from the east, by way of the old Spanish trail, which led us around the south base of the La Plata Mountains and across the Great Sage Plain. It was not difficult to recognize the various features of the country west of the south bend of the Rio Dolores by the descriptions of Dr. Newberry, recently published. Leaving the Dolores at the point touched by the trail, we passed up to the south over the bluffs of the Dakota sandstones, and found smooth, monotonous traveling over the almost unbroken plain. Considerable areas of the fossil-bearing shales of the Middle Cretaceous were observed in localities subject to the least amount of drainage, but the main floor of the plain is composed of the Dakota sandstones.

Ten miles out we came upon a shallow wash in which was a spring. A small band of Utes was encamped here, and on the west bank of the ravine extensive ruins were noticed. This is probably the Surouara of Dr. Newberry. At night we made camp in a pretty little valley about midway between the Dolores and the Sierra Abajo. At this place a small spring issues from the lower slope of the Cretaceous bluff, and affords water enough for a small party. On the following day we left the tortuous trail, which seemed to be leading northward toward the Sierra la Sal, and rode directly westward. After some 40 miles travel we struck the cañon of the Montezuma near its head, and, crossing this, encamped in the evening close under the east slope of the Sierra Abajo.

In traveling 85 miles we had not changed altitude more than 500 feet, and had not varied 200 feet above or below the geologic horizon that separates the Middle and Lower Cretaceous strata. The floor of the plain is everywhere of the Lower Cretaceous sandstones, which have generally a gentle southern dip. Small areas of the shales remain on the less eroded districts. In no case do the stream-courses penetrate to the Red Beds. At the point of crossing, the Montezuma Cañon is only 150 feet in depth, and the walls are composed at the top of about 40 feet of massive, yellowish sandstones, beneath which are soft sandstones and shales, mostly covered with *débris*. The altitude at the crossing is 6,200 feet above sea-level. From the cañon, which runs north and south, a gentle slope of 9 or 10 miles leads up to the base of the steeper faces of the mountains. The sketch (Plate XIII,) taken from the east bank of the Montezuma Cañon, will give a good idea of the general appearance of the eastern face of the group. There is nothing striking in the outlines of the mountains, and there is a total absence of the bold forms and naked rock-masses that characterize the larger groups to the east.

We encamped at the base of the principal eastern spur, where we were unfortunately detained for three days by a rain and snow storm. On the fourth day, the 19th of September, we succeeded in making

the ascent of the main summit. A steep ridge, with steep, smooth sides, projects 4 or 5 miles to the east from the main crest, up which we were able to ride to the highest point. This point is only slightly higher than a number of other summits to the west and north, and is by no means a marked peak; it is simply the highest point of a long east and west ridge. Here Mr. Wilson made the desired primary triangulation station. We were unable, however, to build a monument, as a foot or more of snow obscured the trachytic shingle that abounds near the summit. The latitude of our station was determined to be 37° 50′, the longitude 109° 27′. It is therefore about 23 miles west of the Colorado line, and 58 miles north of the line of Arizona.

The view from the summit is one of more than ordinary interest, since within the circle of vision there is much that has never passed beneath the explorer's eye. To the eastward the view is only interrupted by the La Plata and San Juan Mountains, 100 miles away. In the south are the Sierra Carriso, in the west the Henry Mountains, and to the north the Sierra La Sal, all in plain view, yet outlining a circle nearly 150 miles in diameter, and including an area of 20,000 square miles. This vast area lies beneath us a silent desert, a plateau land cut by innumerable waterless cañons, and dotted with a thousand fancifully carved and brilliantly colored rocks.

To the south lies the broad valley of the Rio San Juan, the delicate thread of green that lines its bank being barely visible through the notches cut by the deep side cañons. Beneath us on the west, yet many miles away, is the Rio Colorado, its general course scarcely traceable through the labarynth of cliffs and cañons. These two streams join in Utah, about 100 miles to the southwest. The lower course of the San Juan can be followed by the eye until it passes the north base of Navajo Mountain, a massive dome-shaped butte that lies a little to the southeast of the junction. In the angle between these streams there is a high red table-land, the Bear's Ears Plateau, which seems to be pretty nearly separated from the surrounding table-lands. It seems to extend to the San Juan on the south, and far out toward the Colorado on the west, while the deep drainage courses that extend north and south from the Sierra Abajo sever it from the Great Sage Plain. It is also severed from the Abajo by a low depression produced by the meeting of the northern and southern drainage along the west base of the Abajo group. As far as the eye can reach, the strata, excepting on the eastern border, are nearly horizontal, and there are only a few low buttes that rise above the general level of the plateau. Of these buttes the two known by the Mexicans as *Orejos Oso*, and two or three inferior ones a few miles further north are distinctly visible. From the interior of the plateau deep cañons open out to the San Juan on the south and the Colorado on the west, which show in their steep faces the brilliant colors of the lower Mesozoic formations. It is probable that the surface strata at least are of this age, but the Palæozoic rocks are doubtless exposed in the cañons of the San Juan and Colorado, as well as in the deeper side cañons. This triangular area comprises nearly 2,000 square miles, and is probably one of the most thoroughly barren districts of the great Colorado basin.

On the east the Bear's Ears Plateau ends in a great monoclinal fold, with the down-throw on the east. The Cretaceous floor of the Sage Plain extends westward to the line of this fold, and occupies about the same absolute horizon as the middle portion of the Triassic formations to the west. The throw of the fold would therefore be approximately 1,000 feet. Although the amount of displacement is so slight the fold is

d, d, North edge of Bears Ears plateau. e, e, Henry

Plate XIV.

a. a. Western Group Abajo Mtns trachyte.
b. b. V Western " " " "
c. c. Northern " " " "

d. d. North edge of Bears Ears plateau. e. e. Henry Mtns. f. f. Probable line of Colorado Cañon. g. g. Red Cliffs. h. h. Region of brownish and gray sandstone and probably bad land. i. i. Red table lands j j Sierra La Sal. k. k. Red Cliffs. l. Casa Colorado. m. m. Great fold in Red Strata—Jura-Trias. n. Cold Spring Cañon. o. Cañon Pintado. p. p. Escarpment of the Lower Cretaceous Sandstones western edge of the Sage Plain.

PANORAMA FROM ABAJO PEAK, LOOKING NORTH AND WEST.

AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)

easily traced by a number of monoclinal valleys that follow its axis from the base of the Abajo group to the San Juan. The ridges that separate these valleys have smooth, sloping faces to the east, and one of them, which presents a continuous line of white or pinkish faces, can be traced south to the San Juan, and far beyond into Arizona. Macomb and Epsom Creeks on the north, and the Rio de Chelly on the south, occupy the more prominent of these valleys.

Beyond the San Juan, to the southwest, the wonderful forms of Monumental Valley can be seen; beyond this the outlines of a broad table-land can be made out, which extends eastward from Navajo Mountain toward the Rio de Chelly, and southward toward the Moqui country, probably connecting there with the "Great White Mesa."

West of our station, which is near the eastern border of the Abajo group, are a number of small partially isolated groups of mountains, which obscure portions of the plateau country beyond. The formations near the west base of the mountains are certainly of the Jura-Trias Red Beds; beyond these we have glimpses of the cañoned region of the Rio Colorado, with its almost infinite series of red, gray, and whitish cliffs. Rising out of this broken plateau region are the Henry Mountains. Their outlines, as well as much of the detail of form, could be made out by aid of the field-glass. They appeared to resemble very closely the vorious groups of trachytic mountains that lie along the eastern border of the Colorado Plateau. The nearest peak of this group is distant about 70 miles from this station.

The Sierra La Sal is a large group of mountains that lies directly north of the Abajo at a distance to the central peaks of some 40 miles. There are a number of finely-shaped summits, somewhat conical in shape, that fall off to the level of the surrounding plateau in long, steep slopes. This group stands quite alone, and is surrounded for the most part by red rocks, but a series of shelving-spurs on the east and west probably retain a capping of the Lower Cretaceous rocks.

Between the Abajo and Sierra La Sal is a broad valley of rather extraordinary configuration. It is drained by the Cañon Colorado of Dr. Newberry, but from this point no particular cañon can be traced. We see only a broad, depressed area, which falls off in a succession of irregular cliffs from the western border of the Sage Plain to the Rio Colorado, over the whole surface of which are a multitude of masses of naked rock, white, red, and gray ridges, hillocks, and monuments smoothed and rounded by the winds and water, the whole being as monotonous, except for the occasional lines of cliffs, as a chopped sea.

The eastern rim of this valley extends considerably to the east of a line drawn between the two groups of mountains, and in the middle part two or more cañoned valleys penetrate the plateau-face of the Sage Plain, and extend many miles eastward toward the Rio Dolores. A glance at the panorama will make the topographic features of this region clear.

The Abajo group, as will be readily seen, lies on the western border of the Great Sage Plain. The western limit of the Lower Cretaceous formation is uniform with that of the plain; south of the Abajo it terminates against the eastern base of the Bear's Ears Plateau, while north of the Abajo it breaks off in the high escarped cliffs that overlook the valley of Cañon Colorado. The dip of the strata of the plain is almost uniformly to the south and southeast, so that the drainage is turned back in those directions from the western and northern borders, leaving but little surface tributary to the Colorado and Dolores Rivers.

The Sierra Abajo consist of a number of small groups of volcanic

summits. The trachyte of which they are formed seems to have reached its present place through a number of channels, although probably from the same nucleus. The masses now exposed were doubtless forced up through narrow crevices or apertures until the yielding formations of the Middle Cretaceous were reached, where the melted material spread out to the right and left in great masses and sheets. The shales are still found in all parts of the group, caught up in a manner identical with that observed in the Late and Carriso Mountains, and the low saddles between the various groups of summits are invariably of these shales.

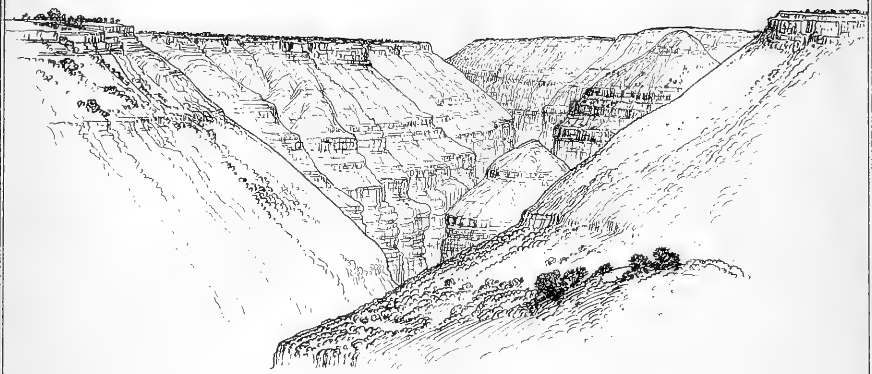
All along the east and south bases of the mountains the sandstones of the Dakota group are turned up at high angles. Near camp, at the base of the primary triangulation station, a double row of hogbacks composed of these sandstones skirt the flanks of the hills. They are somewhat metamorphosed and have a dip of 45°. The slopes above these outcrops are for the most part covered with grass and bushes or with loose slides of finely broken trachyte. In a number of places, however, there are outcrops of variegated shales and slates, and toward the summits considerable masses of trachyte protrude.

The tendency in all parts of the mountains is to weather into smooth, rounded forms, owing, perhaps, to the homogeneous and rather slightly compacted character of the trachyte. Remarkable uniformity is noticeable in the height of the various summits, and some are nearly flat-topped. As their general height above the surrounding floor of the Dakota sandstones represents so nearly the thickness of the Cretaceous shales, the idea is suggested that possibly the great mass of trachyte did not penetrate the very massive sandstones of the Upper Cretaceous, which at that time must have covered the whole region.

There are four principal groups of mountains which, together, cover an area of some 150 square miles. Their arrangement is such that the total extent is a little greater northwest and southeast, but the trend is not sufficiently marked to make a well-defined range. The southeastern section is the only one that comes within the limits of the Colorado survey. This is the group usually seen from the east, and its character will be understood by reference to Plate XIII. Our station was made on the central summit. At the south end is a prominent point almost as high as our station, which presents a sharper summit and more abrupt faces than any other of the entire Sierra.

The drainage of the north and east faces of this group belongs to West Montezuma Creek, while that of the south and west is apparently tributary to western branches of the same stream. The extreme head of the Montezuma seems to be northwest of our station, between the second and third groups of mountains. From this point it circles around to the northeast and south, passing near the north edge of the Sage Plain opposite the head of Cold Spring Cañon. The cañon begins at a point near the east base of the mountains and rapidly deepens toward the San Juan. In the middle part it is upward of 1,000 feet in depth, and the red rocks of the Jura-Trias are exposed. Between the base of the mountains and the Montezuma Cañon there is a considerable area occupied by the Cretaceous shales. East of the cañon the shales only occur on the higher and more protected spots.

Although the country which surrounds this group of mountains is desert-like in the extreme, there is a narrow belt about the flanks and lower slopes that abounds in vegetation. Considerable forests of piñon pines occur about the cañoned region to the east and south. Large groups of these trees are also scattered at intervals over the greater parts of the Sage Plain. Groves of large yellow pines skirt the imme-



A Glimpse into the Dolores Cañon.
Fig, 1.

"Lone Cone" from the South West.
Fig, 2.

diate bases of the mountains and many dense clumps of spruces grow in the more sheltered spots about the summits. Considerable areas are covered by quaking-aspens and scrub-oaks, and on the rich alluvial deposits at the base of the steeper slopes there is a dense growth of wild cherry, service-berry, and other bushes. There is also much good grass, but the omnipresent sage-brush is the chief product of the surrounding plain. There was running-water in a few of the stream-courses, but not in any case a sufficient quantity to be utilized for irrigation.

DOLORES CAÑON.

On leaving the Abajo Peak our party marched eastward toward Lone Cone, the most westerly point of the San Miguel Mountains. Although the two points are distant from each other about 80 miles, both are in plain view throughout the greater part of the distance. Midway between the two points the plain is cut by the cañon of the Rio Dolores. We were led to hope, from the fact that a dim trail extended eastward from the base of the Abajo, that we should be able to find a passage across the river without varying much from a direct course, but were much amazed to find ourselves brought suddenly to a standstill on the brink of a deep and impassable cañon. I made no attempt to descend the walls or to make detailed examinations, as we were still 60 miles from the main camp and entirely out of provisions. We estimated the depth of the cañon to be at least 1,800 feet, and subsequent calculations placed it at upwards of 2,000. The Dakota sandstones form the upper line of cliffs. These are followed by about 800 feet of Lower Dakota and Jurassic strata which form a steep, cliff-broken slope; beneath these were the precipitous water-polished faces of the massive red sandstones. The opposing walls in the lower part of the gorge were so steep and so close together that we were unable to get even a glimpse of the stream. The accompanying sketch will convey a clear idea of the appearance of this interesting cañon.

Turning to the south along the brink of the cañon, a march of 20 miles brought us to a point where I had crossed in 1875. On the second day following, Mr. Wilson reached and made a station on Lone Cone, and on the same evening reached the main camp, which had been made on a branch of the Rio San Miguel. Meantime I had gone on in advance of Mr. Wilson and made some hasty examinations in the Central or Dolores group of the San Miguel Mountains. Thus completing within a period of 84 hours the examination of two important mountain groups, distant from each other fully 100 miles. This great haste was necessitated by circumstances over which we had no control.

SAN MIGUEL MOUNTAINS.

The San Miguel Mountains lie in the extreme northeastern corner of the district assigned to me in 1875, and on the divide between the waters of the Animas and Upper Dolores on the south, and the Rio San Miguel on the north. They constitute a pretty distinct group, the most westerly of the San Juan system of mountains, and form the extreme western angle of the great Colorado highland. There are three distinct groups, the eastern one being the principal; of this, Mount Wilson is the chief summit, and "Lizard's Head" the most easterly summit. This group is separated from the Middle or Dolores group by a low saddle which has been produced by the meeting of the headwaters of the Dolores and a branch of the San Miguel from opposite sides. Dr. Endlich visited the

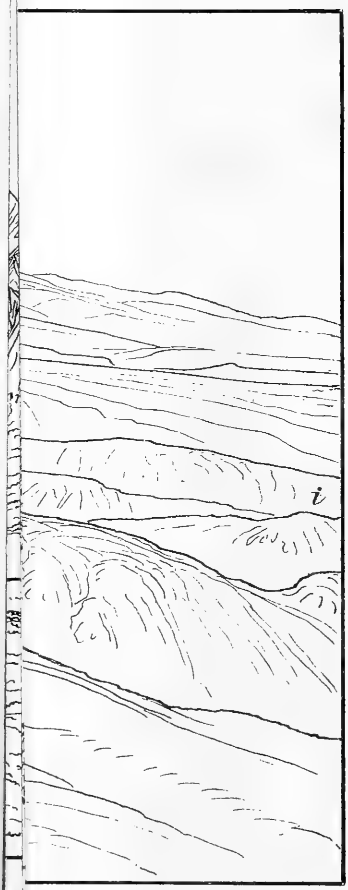
eastern group in 1875, and has described its structure in the report for that year. This is one of the finest groups of summits in the Rocky Mountains, and viewed from the north presents a magnificent panorama. The geologic structure of the western half is quite simple. All of that portion of the summits that rises above 1,200 feet is of trachyte. This is underlaid by Cretaceous shales, in a horizontal position. Interbedded with the shales are a great number of sheets of trachyte. These are somewhat variable in thickness and manner of occurrence, and seem to decrease in number and importance in descending from the main trachyte mass.

The divide between the eastern and middle groups has an altitude of 11,500 feet, and seems only to be preserved at its present height by a heavy bridge-like mass of trachyte, which connects across from group to group and prevents the degradation of the soft shales beneath. In the heads of the valleys north and south of this divide there is a succession of irregular shelves or steps produced by outcropping edges of sheets and masses of trachyte.

The Dolores group is a small, compact cluster of summits, a number of which rise to the height of 13,000 feet. From the central peak three narrow crests radiate, one to the north, one to the east, and the other to the southwest. Dolores Peak is the outer point of the eastern ray, and is directly connected by the saddle mentioned above with the Wilson group. The geological structure is identical with that group. The northern arm falls off abruptly to the north and terminates in a sharp trachytic butte which overlooks the cañon of the Rio San Miguel. The southwest arm connects with the low masses of the Lone Cone group. The conical peak called Lone Cone is a very prominent landmark, overlooking, as it does, all the great plateau region to the south and west. The summit rises to the height of 12,500 feet, and in shape resembles a triangular pyramid. The pyramidal part is a bare mass of grayish trachyte, which rests on a base of horizontal shales. On the southeast and northeast sides; the shales have fallen away from beneath the trachyte so that vertical faces, from 100 to 200 feet in height, have been formed by the breaking down of the trachyte. On the west the long slides of trachytic *débris* make the summit easily accessible. The shales about the base of the pyramid seem to be somewhat metamorphosed, and there is doubtless considerable interbedded trachyte, but a dense growth of pine timber completely covers the middle slopes and makes investigation very difficult.

From the southeast angle of the pyramid a high, timbered ridge extends out to the most southerly summit of the group. This peak is conical in shape, but is inferior in height to Lone Cone. The summit is of trachyte, but the timber reaches so high that the shales, which very probably lie beneath, are not visible. In the ridges or saddles which connect this point with the Dolores group and Lone Cone there are occasional outcrops of shales and trachytes, as in the saddle between the Dolores and Eastern groups. South of this point there is another large mass of trachyte, the relations of which to the surrounding rocks I could not clearly make out. The trachyte caps two low, massive, partially severed ridges, that extend down toward the Dolores. From the south, as seen in 1875, it seems to rest upon the Lower Cretaceous sandstones, and probably at the southeast upon the Red Beds.

Thus it appears that the San Miguel Mountains comprise at least five nearly distinct masses of trachyte, four, at least, of which rest upon horizontal Cretaceous shells, and at a uniform level above the sea. It seems probable, therefore, that they all belong to the same flow, which

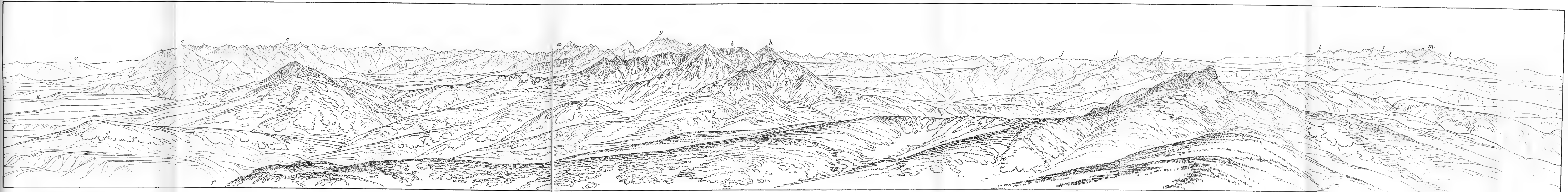


Peak, 13159.

A

TO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

Plate XVI.



a, a, San Miguel Mountains–trachyte underlaid by Cretaceous Shales. b, b, West San Miguel Mts, c, c, North San Juan Mts – Sneffels Group. d, d, Rio San Miguel. f, f. Drainage of the San Miguel. g, Mt Wilson 14280. h, Dolores Pk. 13700. i, i. Dolores River. j, j. Bear River Mtn's – Mezozoic Rocks. K, Trachyte Cone 3 miles South-East of Lone Cone. l, l, La Plata Mtn's. m, Hesperus Peak. 13159.

THE SAN JUAN MOUNTAINS. FROM LONE CONE, LOOKING EAST.

AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)

flow may have had its source far to the east. There seems at least to be no evidence of vertical flow or intrusions in the western portions of these mountains. The trachyte is uniformly gray and compact, and, where rising above timber-line, weathers into the usual gothic forms.

The streams which head about the summits descend in all cases through the Cretaceous shales, and at the immediate bases of the mountains reach and penetrate the hard sandstones of the Lower Cretaceous, and thus the cañons, which can be traced by the eye far out into the surrounding plains and plateaus, have their beginning. To the eye, a more lovely region than that about these mountains cannot be found. The steeper slopes are covered by a dense growth of pine forest, and the gentler slopes below by fine aspen forests, interspersed with many park-like openings in which grass and flowers grow luxuriantly.

BEAR RIVER MOUNTAINS.

South of the San Miguel Mountains, and on the divide between the east and west branches of the Dolores, there is a group of low mountains or hills in which there has been considerable disturbance of the strata. A number of the higher points are capped by trachyte and penetrated by dikes. Strictly speaking, this little range is but a fragment of the great mountain system to the east, from which it has been severed by the great valley of the South Dolores or Bear River. In 1875 Dr. Endlich examined the high region to the east and found it to be chiefly Carboniferous. He failed to recognize the Jurassic and Triassic formations, and therefore makes the Lower Cretaceous strata rest upon the Carboniferous. Although I cannot be positive on this point, I feel confident that strata representing these ages occur all along the cañon of Bear River, and extend to the summits of the Bear River Mountains, although they are certainly neither equal in thickness to nor so characteristically marked as in the cañons farther south and west.

On the south, west, and north the Mesozoic rocks rise to the summits of the Bear River Mountains; on the south and west they soon sink beneath the floor of the great plain, and to the north pass by a gentle dip beneath the San Miguel Mountains.

The eastern portions of the group seem to be composed of Carboniferous rocks, at least 2,000 feet of which are exposed between the summits and the bed of Bear River.

REPORT OF F. M. ENDLICH, S. N. D.

LETTER OF TRANSMITTAL.

OFFICE OF U. S. GEOLOGICAL AND GEOGRAPHICAL
SURVEY OF THE TERRITORIES,
Washington, D. C., February 11, 1878.

SIR: I have the honor to transmit herewith a report on the erupted rocks of Colorado.

This memoir is entirely distinct from my regular geological report of operations during the season of 1876, heretofore transmitted, and may be published independently.

Very respectfully, your obedient servant,

F. M. ENDLICH.

Dr. F. V. HAYDEN,
United States Geologist-in-charge.

ON THE ERUPTED ROCKS OF COLORADO.

By F. M. Endlich, D. N. S.

CHAPTER I.

INTRODUCTION.

Since the earliest times the attention of observers has been directed to those peculiar mountains which, in the language of Pliny, "send forth fire, smoke, and rocks." Active volcanoes first led to speculations as to the interior of the earth, as to the conditions existing beneath the solid exterior crust. Study, developing gradually from amid the mythological and fabulous legends of mediæval times, began to compare the various occurrences known to those who were considered the masters of science and the magic arts. With the great era that dawned in the time of Linnæus, the recognition and application commenced of such features as seemed more or less correlated. Hypotheses were formed upon various subjects, theories expounded, and life was infused into what heretofore had merely been regarded as meaningless forms or the accidents of a direct creation.

In the course of time, after the famous and severe struggle between Neptunists and Plutonists had commenced, the rocks composing mountains and ranges were subjected to more critical examination. The analogous results were pointed out, as demonstrated by groups of varied occurrence, and from these results were drawn conclusions based upon the observations of existing phenomena. It was recognized that where now nothing but rigid rocks were found, there had been at one time the most violent demonstrations of force. Where rivers flowed and lakes placidly reflected surrounding hills, fire and accompanying heat had once reigned supreme. Then the path was indicated that in future scientific research should follow, a definite direction was given to the investigating mind, and reasoning from the known to the unknown was slowly developed.

In Europe, the cradle of our present sciences, the first important results were obtained, and to men like Buch, Werner, Beudant, Herschel, and others are we indebted for the initiation of many ideas with regard to the earth's former history that they obtained from the study of what before their time had been but a sealed book of mystery.

In every portion of the world, so far as hitherto explored, the evidences of volcanic activity have been found. Our limited knowledge permits, as yet, of no systematizing of their horizontal distribution. Even of the existing volcanoes we can say but little, save that they occur in the vicinity of present shore-lines. Inferring from this, we can assume that the same conditions existed at the times when the enormous masses of volcanic material were ejected in regions that now are far inland.

Erupted material is by no means confined to any one geological epoch. The appearance of liquid or plastic masses upon the surface of the earth has occurred since the earliest times, since the formation of a rigid

crust. Evidence shows that during every one of the accepted geological periods rocks have been ejected through the solid strata, and having found their way to the surface, have been productive of changes characteristic in every respect. Geognostically and lithologically such formations can readily be distinguished. Their mode of occurrence, the distinctive features of their form and distribution are unmistakable, should even the lithological or mineralogical constitution afford no direct proof of their origin. In intimate connection with the genesis and structural peculiarities of volcanic masses is the effect they produce upon the topography or orography of any given region. Their presence may be surmised from the configuration of the country, from the detail features of mountains, and other exterior forms. Three groups, mainly, may be distinguished from the stand-point of a topographer: those forming isolated peaks or groups of peaks; those forming mountain chains and ranges; and the most complete, those forming extensive highland plateaus. Each of these is referable, within certain limits, to certain classes of eruptive rocks, and thus the exterior appearance will furnish a suggestion as to the material composing any one of the groups mentioned. Great variations naturally occur from any one rule that might be laid down, and a systematic arrangement based upon distinctions of this kind must necessarily, therefore, be but imperfect.

Not only for the geologist and topographer are these erupted masses of direct importance, but also for the miner and agriculturist. Discoveries and observations have developed a knowledge of certain facts in connection with the occurrence of masses belonging to this group, that demonstrate the value of acquaintance with them for one interested in economic features. Mines of great magnitude and wealth have been found within their limits, both in Europe and on this continent. Although geological science is but young as yet, the knowledge gained has been aptly applied, and we have learned to utilize even the small amount we posess to the greatest possible advantage. It is evident, therefore, that the more thorough recognition of every feature connected with such a class of rocks will furnish additional information that may directly be applied in the process of supplying our wants. Thus the agriculturist has learned that—conditions of climate and elevation being not unfavorable—he can successfully draw revenue from soil resulting from certain rocks, while others will claim by far more of his attention and labor.

In the subjoined pages all questions pertaining to the origin, distribution, general and special features of the volcanic formations of Colorado shall be considered. Wherever requisite, for the purpose of clearer understanding, comparisons have been instituted with the analogous or identical formations of other regions, which in part, at least, have been more thoroughly studied than those to which this paper is devoted. Colorado offers more favorable points of discussion, perhaps, than any other region of the United States, and as four years' work there has brought me into constant contact with the consideration of volcanic groups of that State, I shall endeavor to present as complete a synopsis of their entire character as my investigations enable me to prepare. The survey of the State is finished, the distribution of geological formations throughout its entire area is known, and this treatise is, therefore, presented as a review of one of its most interesting classes of rocks.

Using the more comprehensive term, erupted masses, it becomes a matter of some difficulty to draw the line of distinction. Where original metamorphic rocks end and those brought to the surface by eruption

begin, is frequently almost impossible to determine. Taking the view which presents metamorphic rocks as the resultants of the action of heat upon originally sedimentary deposits, an action often accompanied by disturbances of position, the definite line between them and truly eruptive rocks cannot so readily be recognized. As a rule, it may be stated that all those rocks are to be considered as eruptive which break through or are ejected through fissures in rigid strata or masses, and either reach the surface or remain hidden beneath it. The latter case includes the phenomenon of intrusion, which, however, occurs more particularly in sedimentary formations. Within them the difference of regularly deposited and eruptive material is by far more evident than in the former instance. Although the strata of sedimentary beds may have assumed any position, any angle of inclination, the intrusion or ejection of erupted rock is always sufficiently characteristic to be recognized, both by the different constitution of the rock and by the result of the forms produced.

Here, too, as in the preceding case, the erupted rocks may reach the surface or may only reach within a certain distance of it. Erosion, in the latter instance, not unfrequently discloses them. If they have reached beyond the exterior limits of the sedimentary beds, their presence is generally indicated by the formation of isolated hills, mountains, mountain groups, or plateaus. Thus a ready recognition, separating them from their surroundings, is established.

It lies in the nature of the subject that we should find almost innumerable varieties representing this class of rocks, and investigations have thus far supplied us with an ample list of names. In mode of occurrence, in age, and in lithological character the erupted rocks differ greatly among themselves, and to these features is due the large number of specific distinctions that have been made. As a rule, it may be stated that the older eruptives differ more from the metamorphics in their chemical nature than some of the younger ones. A metamorphic series is merely the altered representative of some distinct group of beds, while an eruptive one, although it may be but the same group, is so thoroughly changed by fusion and subsequent cooling, that every vestige of its former physical condition is obliterated. In metamorphic groups stratification may in part be preserved, the differences indicating origin from mineralogically separable beds may be noticeable, but an erupted rock is usually so thoroughly and uniformly remodelled, that no clue to its original condition can be obtained from a study of its physical character only. It is impossible to draw any line of distinction which would divide the entire series of eruptives into appropriate, well-defined groups. Bunsen has attempted a primary classification (to be alluded to below), but it is certainly insufficient. At best, they can be said to belong to one grand division of the geological history of our earth, supplying one important factor in the formation of its crust, and fulfilling a definite mission as regards its exterior surface. For systematic purposes it is requisite, however, to adopt some basis of separation, even if artificial, and for that purpose we can scarcely find one answering as well as the chemical.

Without drawing the lines too closely, a chemical primary classification has a more or less direct bearing upon one very important question, viz, that touching the *genesis* of the erupted masses. Although by no means sufficiently indicative of any one method of operation, the results as furnished us by chemical examination afford indirect hints at least as to the character of the agents employed in the generation of eruptives. So far as our observations extend, their present existence is attributable to one main cause. This cause is heat. Not only do we infer this from the demonstrations accompanying eruptions of the pres-

ent day, but the knowledge of the chemical changes effected in various compounds by heat justifies the assertion. In spite of the common origin, as to this one factor, the differing character of the original unfused material, and more particularly the results produced by various methods of cooling, have supplied us with so many specifically distinct occurrences.

In speaking of the origin of eruptives these features will be more thoroughly discussed and instances referred to where they directly apply

CLASSIFICATION.

At all times it is a matter of difficulty to arrange any satisfactory lithological classification. This is more particularly the case when we deal with eruptive rocks. The means at our disposal whereupon to base any definite system are limited, and in several instances unsatisfactory. At first sight a chemical basis appears very acceptable, not only for the primary, but also for minor divisions. It is, however, open to the objection that in many cases it would be requisite to make analyses before being able to decide as to the species of rock under consideration. Among the best systems offered is that used by Cotta.* He accepts Bunsen's primary division into *basic* and *acidic* rocks, and determines the species of each group in accordance with its mineralogical constitution. This method furnishes the means, first, of a definite ultimate arrangement, and, secondly, of determining at once the precise position occupied by the specimen under examination.

It would seem that a classification based upon the geological age of the rocks might prove serviceable. One main and decided objection, however, asserts itself in the difficulty of determining this age in many instances. Were we in the possession of all the necessary data a system could, no doubt, be constructed that would answer admirably well. It would necessitate the distinction into species utterly irrespective of genetic or mineralogical affinities, however, and probably create more confusion than benefit. Of late years the microscope has been of great service in determining lithological species, more particularly those belonging to the eruptive class. Under the skillful management of Zirkel this method has achieved a reputation justly earned by its excellent results. In spite of its correct interpretation and by far more accurate discrimination than any other means will supply, its very general application for classificatory purposes will remain limited. The preparation of the rocks before the examination can take place, the transportation of instruments, and the comparatively large amount of practice required for the successful completion of work will prevent this method from becoming the basis for a universally accepted classification of rocks.

Of all the means at hand, therefore, the one adopted by Cotta answers best for our purposes, and it is with special reference to his general system of classifying (without adhering strictly to his arrangement) that the rocks in question shall be treated of below.

Europe exhibits a number of typical localities where volcanic—in contradistinction to plutonic—rocks occur. It is a few only of them that enter into consideration here. The generally-adopted application of names to European lithological groups is conformable with our own, with the exception that our groups are by far more varied; hence division and subdivision more thoroughly carried out. There, as here (speaking of Colorado more especially), the trachytic and basaltic

* Geologie der Gegenwart, Leipzig, 1872, p. 20.

groups are the most important. In France the mountains of the Auvergne region are composed of trachyte; in Central Germany the Drachenfels group, formed by the same rock, has become famous; and the basalts along the Rhine and some of its tributaries are well known. Toward the eastern portion of Germany, trachytic series again occur, denoting their presence by the formation of isolated hills or mountain groups. The "Vogelgebirge" of Hessia and the isolated outcrops throughout Southern Germany belong to the Basaltic era. To the latter, also, we count the volcanics of the British islands and of Sweden and Norway.

Showing closer affinities, perhaps, than the volcanic groups of any other region, with those of Colorado and the Rocky Mountains generally, are those of Transylvania. Richthofen, whose study of our western country has been productive of such excellent results, has given his attention to the volcanics of that country, and to him, besides in a great measure to Beudant, we owe the knowledge of an existing similarity between the two.

In a general way, it is possible to correlate the volcanics of the two continents. In North America, however, we find all the features represented on so grand a scale that direct comparison will furnish but unsatisfactory results. In variety of forms produced, and variations of constitutions exhibited by volcanics, our North American are unique, though not entirely distinct from the European. We deal with broader areas, with phenomena produced on a very large scale, and the difference, first, between foreign occurrences, and, secondly, among the North American volcanics themselves, is proportionate thereto.

From the comparatively incomplete observations that are at our command at the present time, respecting the volcanic formations of the western portion of our continent, we are enabled to say that our series, speaking from an evolutionary stand-point, is by far more complete than the European. It is in the West but a step from the prehistoric to the active volcanoes, while east of the Atlantic the difference is strongly marked. While we are often in doubt whether an occurrence of scoria or lava may be even more than a few hundred years old, the former volcanoes in the interior of Europe present a more ancient type, reminding less of the characteristic material that composes and issues from volcanoes of to-day. It is this comparative completeness of our series that produces the difficulty in devising any thoroughly satisfactory system, which will not only define the numerous lithological varieties, but at the same time bear distinct and definable relations both to genesis and age of the rocks thus classified.

As proposed by Richthofen,* the classification for the volcanic rocks of our western mountain-ranges is one based essentially upon their age. Within certain limits they all belong to a comparatively restricted geological period, and by determining their relative positions, very applicable data can be obtained. Both in Europe and America certain groups have been recognized as bearing definite relations to each other, and the determinations made on both continents agree very well. For all practical purposes the system as introduced by Richthofen certainly answers, and, as it is one designating minor divisions, it can be utilized in conjunction with any more or less artificial classification that furnishes the characteristics for primary groups. In the subjoined pages, therefore, this classification shall be adopted in the main, with such additions as may seem to be required, and in connection with a primary division based upon simple chemical constitutions.

* Mem. Cal. Ac.. Sci, 1868. Vol. i, part ii.

OCCURRENCE OF VOLCANIC ROCKS ON THE NORTH AMERICAN CONTINENT.

The North American continent can appropriately be separated into three sections for our purposes—into the eastern, middle, and western divisions. In the first the volcanic occurrences are sporadic, limited as to extent, and all or nearly all belonging to one period of relatively recent age. In the second, the development of volcanic activity was at its minimum. Very few occurrences belonging to that group of geological history have taken place in that section, and wherever found are but local, and of no importance either in the geological series or topographical features of the region exhibiting them. Differing from both of these, and presenting groups of the utmost interest and decided variation, is the western section. Beginning with the Alaskan peninsula, we observe volcanics composing portions of the continent* and many of the outlying islands. Throughout the mountainous chain, extending through British Columbia southward toward the United States, volcanic occurrences have been observed. Explorations of that mountain system are wanting which would furnish us with sufficient data to make any generalizations whatever, or even to prevent those meager data obtainable in a connected form. Within the area of the United States we are more thoroughly acquainted with the occurrences of volcanic rock, and it is to the writings of explorers like Hayden, King, Newberry, Richthofen, and Whitney that we are indebted for our knowledge of their existence and characteristics.

Through the Western States and Territories the number of varieties exhibited by volcanic eruptions not only, but also the enormous horizontal extent of the groups, invite study and investigation. Owing to the comparative completeness of the series, reaching from the Plutonic eruptives to active or nearly active volcanoes of the present day, they furnish a more complete record of the history of volcanic rocks than any other region thus far known. In the heart of the Rocky Mountains we meet with innumerable exposures of the older groups, which are replaced by younger ones as we proceed west and south toward the present shore-lines. In California there are basaltic groups, which, according to Whitney, may almost be regarded as still active. In Utah and Nevada, Gilbert has found regions that looked remarkably "fresh," and Powell has discovered legends among the Indians referring to volcanic eruptions during historical times.

Southward, beyond the boundary of the United States, the volcanic areas continue into Mexico and Central America. As we approach their shores, we find that the formations (volcanic) are younger, until still active volcanoes are found. This state of things continues on through the Cordilleras to the southern end of South America. We have, therefore, in the Rocky Mountains of the United States an area of exhausted volcanic activity. Upon observation, it will be found that the former volcanic outflows and eruptions took place along a line approximately corresponding with the present shore-line of the Pacific Ocean. The arrangement of our mountain ranges is essentially a north to south one, and associated therewith we see that the arrangement of sedimentary formations is parallel. It is to be expected, therefore, that we should find the demonstration of volcanic force along a line nearly parallel to that of maximum sedimentation. This is in reality the case. Where the process of sedimentary deposition is still going on, we ob-

* Dall, Alaska and its Resources, 1870.

serve the existence of the youngest volcanic activity, reaching to the present day. The Western section of the North American continent may consequently be subdivided into two groups, into the ancient and recent volcanic. Of these, the former may be regarded as existing in the Rocky Mountains proper, while the second comprises those portions contained in the ranges near the Pacific Coast. This latter series is the one that extends directly southward, and finds its first great development in the volcanoes of Mexico and Central America.

It is not the object of this paper to discuss extensively any of the eruptives besides those of Colorado; therefore these brief indications as to distribution must suffice. We have in Colorado erupted rocks that belong to the first group. Perhaps no section of the Western country is so well adapted to the study of volcanics as Colorado. This is owing to the great variety of rocks exhibited and the large expanses they cover. During the four years occupied by the survey of this State, all occurrences there have been thoroughly studied, and we are enabled now to present a more complete synopsis than probably can be furnished of any other Territory or State. In the subjoined pages, therefore, the erupted rocks of Colorado are the main subject of discussion, and only such cases as are necessary for comparison will be introduced.

OCCURRENCE OF ERUPTED ROCKS IN COLORADO.

Throughout the State we find volcanic rocks distributed. In part they are continued into adjacent Territories. Taking a comprehensive view of all the groups, both lithologically and topographically, it appears that Colorado contains occurrences which, all taken together, form a closed, a compact series. Whichever volcanic area may extend beyond the limits of the State, or whichever group of characteristic formations may be continued into either New Mexico or Utah, we nevertheless find its most important portion in Colorado. Very justly, therefore, the volcanic groups of the State may be treated as one, representing typically an important era in geological history. They may be regarded as chapters of the book which is commenced and finished within the area assigned to the State.

Distribution.—During the progress of the survey, volcanic rocks were almost everywhere encountered. Extensive areas were found, where all other formations were successfully hidden beneath the superimposed masses of volcanic material. Again, the latter had formerly covered much that erosion gradually brought to light once more, and we now see it in isolated particles. Groups, whose isolation and small horizontal extent is a leading characteristic, occupy prominent positions in the landscape of Colorado.

We find the volcanic exposures along the various mountain-ranges of the State more connected than elsewhere. In the Front Range, in the vicinity of Pike's Peak,* we first meet with extensive volcanic areas. Occupying a position which imposes them upon the granite of that range, they form for some distance its most elevated points. Proceeding westward, we are accompanied by volcanics into the southern end of South Park.† Although not so continuous as southwest of Pike's Peak, the areas are well defined and sufficiently prominent to be of importance orographically.

Farther north, in Middle Park, we again find isolated groups of volcanic rocks.‡ In the vicinity of the Hot Springs basaltic outcrops oc-

* Rep. U. S. Geol. Surv., 1873, p. 318. † Rep. U. S. Geol. Surv., 1873, p. 219.
‡ Rep. U. S. Geol. Surv., 1873, p. 162.

cur, also, a breccia, referred to Dolerite. From Middle Park southwest but few volcanics are met with, until we reach the region of the Grand Mesa.* In the Elk Mountains, volcanic rocks of the greatest interest occur. Their unique character, as regards both constitution and association, claims for them the utmost attention. By far the largest area is that of the Uncompahgre and the San Juan Mountains.† Stretching for miles and miles, they there present a perfectly unbroken surface. In the interminable varieties that have there been produced, and in the harmony of detail arrangements, we have a series that may justly be compared to a succession of sedimentary beds.

In the Sawatch Range, in the Sangre de Cristo, and in the Wet Mountains, we have areas that, although isolated now, tend to show a former connection over a large expanse of country.

As typically isolated groups, isolated by virtue of their genesis, we may regard the Spanish Peaks, La Plata Mountains, Mount Wilson, Sierra Carriso, El Late Mountains, Sierra La Sal, and Sierra Abajo. Although the latter two are not within the boundaries of Colorado, they are very near, and are possessed of the same characteristics that elsewhere must be regarded as typical for certain groups of Colorado.

A large area of volcanic formations may be found in the southwestern and southern portion of San Luis Valley. Though directly a continuation of the same formations in the Southern San Juan Mountains, their appearance in so great a mass in a valley is noticeable.

Local outcrops of various volcanic formations, occurring in the form of dikes and buttes, are frequently found throughout the State. Several of the species of volcanic rocks participate in their formation, and greatly dependent upon their composition will be the exterior appearance they present.

From this distribution it will be seen that the bulk of volcanic formations falls into Southwestern Colorado. Whereas the outlying groups may be regarded as of but inferior importance, qualitatively, we there have an enormous mass of the material.

As might be expected, the distribution of volcanic formations within certain areas is productive of definite orographic effects. Dependent, to some extent, upon the lithological character of the rocks is the result observed. Differences of such constitution must be sought for in the physical rather than the chemical nature, and proportionate thereto are the distinctive features presented. Wherever volcanic rocks cap either prozoic‡ or sedimentary formations, their vertical limits can generally be readily distinguished. As a rule, if superincumbent upon sedimentary beds, they are a protection to them from erosive agents. When intrusive, either conformable with the strata or across them, their action is frequently a preserving one, although not in so marked a manner as in the former instance. In connection with the topographical features as modified by the occurrence of volcanic rocks, we find those pertaining to the drainage. Non-sedimentary and sedimentary formations are, at all localities, found to have been subjected to by far more powerfully-acting disturbing agents than the volcanics. While, therefore, we find the latter more frequently in an undisturbed position, the former have been removed in various directions from their original places of deposition. This must, of necessity, produce a more schematical arrangement of the drainage within volcanic areas. So far as observation goes, it shows that in Colorado the volcanic drainage exhibits a more radial and spiral type than can be found within the area of any other class of rocks.

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* Rep. U. S. Geol. Surv., 1874.

† Reps. U. S. Geol. Surv., 1873; 1874; 1875.

‡ See p. 104.

Great homogeneousness of the component material, and its more regular arrangement with reference to under and over lying beds, facilitate the retention of original distribution of drainage. Within the San Juan and Uncompahgre Mountains such features can, perhaps, be best observed. There the great horizontal extent as well as the vertical dimensions of the volcanic rocks have afforded the most satisfactory opportunities for a typical development of such features. Generally, too, a volcanic region is well watered, owing to the comparative impenetrability of the beds. Incident thereupon are promotion of vegetation and formation of soil. Exceptions to this rule are certainly not wanting, least of all in groups of high, abrupt mountains, and in plains where the absence of water has not permitted vegetation to flourish.

CLASSIFICATION OF ERUPTED ROCKS IN COLORADO.

In Colorado by far the greater mass of volcanic material must be assigned to one geological epoch. This epoch is divisible into two periods. Making, primarily, this distinction, we have made the first step toward a classification. Very few cases only were found where erupted material was evidently in no connection whatever with that of the accepted epoch. Isolated occurrences of porphyritic rocks, older, geologically speaking, than the remaining eruptives, represent these cases.

Enumerating the erupted rocks of Colorado, beginning with the oldest, we have granite, porphyry, andesite, trachyte, rhyolite, porphyritic trachyte, dolerite, and basalt. Separating these primarily into Bunsen's divisions, basic and acidic, the result is as follows:

Basic.	*Acidic.*
Diorite.	Granite.
Euphotide.	Protoginyte.
Porphyry.	Andesite.
Dolerite.	Trachyte.
Basalt.	Porphyritic trachyte.
	Rhyolite.

Of these the diorite, euphotide, porphyry, and granite must be classed, according to Cotta, as *plutonic*, while the remainder are *volcanic*. These two primary divisions furnish us with the foundation whereon to build. For the western acidic volcanics we have Richthofen's admirable classification. He separates them into propylite, andesite, trachyte, and rhyolite. Four years ago* I comprised all of these under the term Trachorheites. Subsequent explorations proved the existence of a group totally distinct from the trachorheites. It is separated from them by its mode of occurrence, the lithological character of its rocks, and by its relative position. Dr. Peale† has distinguished it under the name of porphyritic trachyte. *Trachyte-porphyry* of European geologists, their liparite‡ has a certain resemblance to it, but differs in many essential features.

So far as could be determined, we have in Colorado no propylite. It is possible that it exists there, or rather its representative, but either its intimate association with younger volcanics or a change in its composition has rendered it undistinguishable. Andesite, trachyte, and

* Rep. U. S. Geol. Surv., 1873.

† Bulletin U. S. Geol. Surv., Vol. iii, No. 3.

‡ Cotta, Geologie der Gegenwart, p. 54.

rhyolite are all readily recognized wherever met with. In 1874 I subdivided trachyte into four groups.* Of the basic volcanic products we find only dolerite and basalt, the latter represented by numerous varieties. A synopsis of the erupted rocks found in Colorado, classified primarily upon chemical, secondarily a genetic, and thirdly upon a chronological basis, beginning with the oldest, will furnish the following result:

BASIC.		ACIDIC.
	Plutonic.	
Diorite.		Granite.
Euphotide.		Protoginyte.
Porphyry.		
	Volcanic.	
		Andesite,
		Trachyte.
		Trachyte, 1.
		Trachyte, 2.
		Trachyte, 3.
		Trachyte, 4.
Dolerite.		Porphyritic trachyte.
Basalt.		Rhyolite.

It seems difficult to determine the relative age of porphyritic trachyte as compared with rhyolite. At many localities the one seems to grade into the other. I am not aware that any point was found where the two, each typically represented, were in contact. From all analogies I should judge them to have been erupted at very nearly the same time. At one locality, perhaps, a rhyolitic eruption may have been completed before the nearest one of porphyritic trachyte took place, and *vice versa*. I place the latter immediately after trachyte, for the reason that it is less acidic than rhyolite, and regard its definite age with reference to this class of rocks as not fully established. Genetically it should be removed from the trachyte and cede its position to rhyolite.

The classification as above given will represent all the erupted material found in Colorado. It is difficult to find an acceptable basis for division, but, it seems to me, that for this State, and perhaps others, the arrangement is the most satisfactory. Occurring in connection with these groups are rocks that have frequently been regarded as independent representatives either of definite kinds of eruptive activity or of characteristic genesis. I allude to such instances where obsidian, perlite, pumice, &c., have not been regarded as minerals merely, but have been designated as rock-species. Their presence or absence certainly is of importance considering the circumstances attendant upon the genesis of the rocks they are associated with.

CHAPTER II.

PLUTONIC ERUPTIVES.

BASIC PLUTONIC ERUPTIVES.

Diorite.—Within the metamorphic areas, more particularly of the Front Range, a number of dikes occur. Traversing the granite in various directions, we find a hornblendic dike-rock, closely resembling diorite. "It is composed of small crystalline particles of hornblende and

* Rep. U. S. Geol. Surv., 1874.

oligoclase, joined together rather loosely, without the slightest intimation of a *magma*."* No definite relation, as borne by these dikes to the surrounding metamorphic or prozoic rocks, could be observed. Without rule they are distributed, striking in a definite direction within very circumscribed areas, but in no further connection with each other. Probably they are dikes that were formed catogeneously at the time of metamorphosis. Their mineralogical composition is identical with that usually accepted for diorite, and I therefore cite them as such. Similar in many characteristics to this is the following species:

Euphotide.—In the vicinity of Mount Ouray this rock occurs. It is composed† of a dark-green diallage and white oligoclase. Chlorite and magnetite are accessories. More important than the diorite, this rock builds up a considerable portion of the Ouray group. It is intimately associated with the granite, which there appears to be the younger of the two. In determining the specific position of any of the hornblendic rocks within a metamorphic area the greatest caution is requisite. There is but little doubt that the same hornblendic rocks that we now can claim to be metamorphic, may have been, from one or the other cause, eruptive. In that case they will not necessarily present any distinguishable mineralogical features, but the method of their association, the mode of occurrence, must furnish the decisive evidence. Whenever this cannot be obtained from such characteristics, the identification remains questionable. We may have before us instead of an erupted rock, simply the metamorphosed product of one of the earliest sedimentaries. Unless, therefore, much labor and time should be spent upon this class of rocks in Colorado, I cannot conceive that any satisfactory results will be obtained. At best their horizontal distribution is but limited; in their detail features they show so many variations, however, that the most elaborate work will be required before they can all be assigned to their proper places. I have chosen the examples of diorite and euphotide as the best determined out of a number. Among it such rocks as gabbro, hypersthene, and others might be mentioned.

Porphyry.—Very few occurrences of porphyry in Colorado have been noted. The most important and best known porphyry dike of the State is that at Gold Hill.‡ On either side of this dike, which traverses granite, is located a remunerative gold mine. Several smaller dikes are found within a short distance of this one, but are of minor importance. Great interest attaches itself to this occurrence from the presence of tellurium compounds in the metalliferous veins adjoining the porphyry. A purplish-gray paste, varying to greenish, incloses very fine crystals of feldspar. Orthoclase, with laminæ of oligoclase, and small crystals, apparently of microclinite, are the inclosed minerals. Another porphyry dike was observed in the Sangre de Cristo Mountains.§ This has broken through Carboniferous strata, and now appears near the summit of a high peak near the Crestones. A dense, pink matrix incloses small crystals of feldspar and dihexahedral quartz.

Near Central City a number of porphyry dikes occur.‖ The largest one of these is located on Quartz Hill. Several of the others, Bobtail, Gregory, and Mammoth Hills, show similar dikes near their highest points. Essentially, the rock is a quartzose porphyry. Its paste is very compact, light green to yellow, gray, and brown. On Gregory Hill very fine crystals of orthoclase are contained in the porphyry. They occur simple and as Carlsbad twins. Owing to the composition of the paste,

* Rep. U. S. Geol. Surv., 1873, p. 325.
† Rep. U. S. Geol. Surv., 1873, p. 338.
‡ Rep. U. S. Geol. Surv., 1873, pp. 144, 686, and 688.
§ Rep U. S. Geol. Surv., 1873, p. 328.
‖ U. S. Rep. Geol. Surv., 1873, p. 281.

the crystals weather out very readily. Some portions of the porphyry contain minute crystals of hornblende. All of these dikes are in contact with either granitic or gneissic rock. No marked regularity of course can be observed.

Taking a general view of all these basic plutonic dikes, they are found to have a number of features in common. Usually they occur without any apparent provocation, several of them form a small group, and each member of this group agrees, in its characteristics, with the others. As a general thing their strike may be said to be approximately north and south. Their width is variable, from a few feet to several hundred. Accessory minerals, such as feldspar, garnets, small crystals of magnetite, pargasite, and others are contained within the dike-rock. With the exception of the one instance, all these dikes are associated with presedimentary rocks. Their age, therefore, may be regarded as an open question. My impression is that the diorites are oldest, the porphyries youngest.

ACIDIC PLUTONIC ERUPTIVES.

Granite.—In the northern part of the Sangre de Cristo Range an eruptive granite occurs.* It is readily distinguished from the older, metamorphic. Orthoclase is light gray, white, and yellowish; small crystals of oligoclase are dispersed throughout; quartz is colorless or milky white; the mica black, sometimes in small six-sided crystals. The appearance of this granite upon the surface was accompanied and probably produced by the demonstration of powerfully-acting vertical force. Carboniferous beds of great thickness were thrown upward so as to form a steep, anticlinal range. In the centre of this we find the granite. Its relative position to the sedimentary beds is constant throughout. No cases of intrusion were observed, or even the formation of dikes within the unchanged sedimentaries. A considerable amount of metamorphism has taken place, totally changing some of the oldest strata. North of Hunt's Peak and south of Mosco Pass the eruptive granite again is lost, and only metamorphic granites are found in other portions of the range. From the entire character of the range it would appear that the disturbances there were not owing, directly, to the eruption of the granite, but that the latter thereby found room to escape upward.

The most important and typical occurrence of eruptive granite in Colorado was observed in the Elk Mountains. Along the line of a definite axis this range has been elevated, appearing "to be an example of a sudden, violent, or catastrophic action."† Granite forms the central mass, the underlying bulk of the range, while the sedimentary beds, many thousand feet in thickness, have been contorted, overturned, and broken. Mr. Holmes has published‡ a very excellent diagram, representing the exposure of eruptive granite along the main axis of the range. From this it appears that the main exposures of eruptive granite occur in the Snow Mass and in the White-Rock groups. Between these two the granites are hidden from sight by the contorted sedimentary beds. These form an S-shaped fold here, overlapping from the eastward. Probably the large masses of sedimentary strata were thoroughly broken, and finally removed from the localities where now the granite is exposed. Dr. Hayden says,§ "This is a grand illustration of an eruptive range." In spite of the violent disturbances to which the sedimentary strata have here been subjected, the range presents essentially the type of an anticlinal. Acting along a definite axis, the trend of

* Rep. U. S. Geol. Surv., 1873, p. 324.

† Rep. U. S. Geol. Surv., 1874, p. 55.

‡ Ibid., p. 70.

§ Rep. U. S. Geol. Surv., 1874, p. 55.

which is about northwest to southeast, the granites have been forced upward, carrying before them the enormous mass of sedimentaries superimposed. By studying Mr. Holmes's admirable sections (Report, 1874) we will find that the eruptive granite reached the surface in greatest quantities at such points where the vertical dimensions of the sedimentary beds showed their smallest development. In other words, at the points or along the line of least resistance. A large number of dikes traverse the sedimentary beds adjoining the trachytic areas. Many of them are undoubtedly granitic; others appear to be trachytic. Of these latter Dr. Peale says,* "Some of them would probably be proved to be trachytic, but I am of the opinion that if they could be traced to the granite they would be seen to grade imperceptibly into it."

In mineralogical character the granites of the Elk Mountains approach those of the Sangre de Cristo. The general appearance shows a white or gray color. Orthoclase, oligoclase, quartz, and muscovite, with some biotite, compose the rocks. Associated with the granites of the range are some porphyries and diorites. I am inclined, however, to attach but little importance to their presence, as they probably belong to the same eruption that produced the elevation of the range.

We have, in the Elk Mountains, an example of an eruptive range that offers the most favorable opportunities for study. Not only do we find the granites and sedimentary beds in direct contact, but we find younger eruptive rocks in the region immediately adjacent. Although perhaps not in absolute local connection with the granitic masses, these younger eruptives stand in the most intimate causal relation. They belong to the series of trachorheites and will be discussed below.

From Mr. Holmes's sections it appears that the Middle Cretaceous shales have actively participated in the folding and plication of sedimentary strata. From the Silurian up the regular succession of formations—as characteristic for Colorado—is represented in the Elk Mountains. All these have been subjected, uniformly, to the most severe disturbances. We can, therefore, from this evidence, place the elevation of the range into a period very near the close of the Cretaceous formation. This, at the same time, agrees with the usual experience, which claims for the greatest eruptive activity in Colorado a time near the close of the Cretaceous, mostly, however, approaching rather the Tertiary epoch.

On Station 38 of 1873, south of the Gunnison, an occurrence was observed that I am inclined to bring into connection with the eruptives of the Elk Mountains. Geologically considered, station 38 may be regarded as the extreme southern extension of the Elk Mountain Range. The granite there is associated with the same sedimentary beds as in the Elk Mountains.† We have, in that instance, an eruptive granite, which has broken out through a great thickness of sedimentary strata, has formed a high, prominent peak, and was succeeded by an eruption of trachytic lava. The force which permitted the protrusion of this granite succeeded in forming a quaquaversal arrangement in the sedimentary strata. In lithological characteristics this granite agrees closely with that of the Elk Mountains and of the Sangre de Cristo. Its relative position to older formations admits of no doubt as to its method of appearing. So far as could be determined, the time of this granitic eruption fell into the same period that is accepted for the elevation of the Elk Mountain Range proper. Isolated occurrences of such granites may be found, but they are of no considerable extent.

* Rep. U. S. Geol. Surv., 1873, p. 261.
†Rep. U. S. Geol. Surv., 1873, pp. 337 and 340.

Protoginyte.—In addition to the granites proper, a variety very nearly related to it was observed in Colorado. At the head of Chalk Creek a very interesting rock was found to compose several high peaks of the Sawatch Range.* In my report upon that section I have regarded it as porphyritic protoginyte. It occupies a circumscribed area with the granitic region, and may, perhaps, be regarded as a granite with the substitution of mica by chlorite. In all its general features it closely resembles the granite. I consider it expedient, however, to mention it here, as one of those rocks presenting typically the character of an eruptive. In age I consider it synchronous, or very nearly so, with the granite of the Sangre de Cristo. A crystalline aggregate of orthoclase, oligoclase, quartz, chlorite, and hornblende constitutes the rock. Orthoclase occurs in Carlsbad twins, inclosing laminæ of white, transparent oligoclase. Crystals of the latter are dispersed throughout the rock. Quartz is gray and transparent; it is found, partly, in fragmentary pieces, partly in grains. Chlorite substitutes the mica of granites, is green to black, and occurs in fragments and small crystals.

* Rep. U. S. Geol. Surv., 1873, p. 337.

CHAPTER III.

VOLCANIC ERUPTIVES.

ACIDIC VOLCANIC ERUPTIVES.

The class of acidic volcanic eruptives is the one by far most fully represented in Colorado. To it belong the trachorheites and the porphyritic trachytes. In using the comprehensive term of trachorheites, I include therein all that uniform series of massive eruptives older than the porphyritic trachytes and add to it the rhyolite. For the sake of classificatory convenience the rhyolite will be enumerated directly after trachyte No. 4, thus leaving the question open of its relative age, as compared with porphyritic trachyte.

It has been mentioned above that propylite was not positively recognized. This rock is the timazite of Transylvania, and, according to Cotta, should be placed among the plutonic acidics. In case its existence should hereafter be established in Colorado, and it be found in connection with the younger portions of the trachorheitic series, it should be classed among the volcanic acidics. The development of volcanic rocks in Transylvania is not so complete nor so typical as it is in our Western Territories, and, therefore, as the oldest member of the group, it could readily be regarded as a plutonic eruptive. In Colorado more particularly, however, the correlation of groups is so well defined, that if propylite should occur in connection therewith it could not be separated from the acidic volcanic eruptives.

TRACHORHEITES.

ANDESITE.

As can readily be understood, the andesites, the oldest group, have been subjected to many changes. Their position, with reference to subsequent eruptions, and their lithological constitution have rendered them liable to alteration. Thus we find, at many places, a very complete transition from typical andesite to typical trachyte. During 1873, while in the field, I was inclined to refer many of the eruptive rocks to this group; but subsequent examinations showed me that its occurrence, or rather its appearance upon the surface, is comparatively limited.

Perhaps the best exposures of andesite in Colorado may be found in the Front Range, west of Pike's Peak.* There the volcanics have found their way to the surface directly through gneissic and granitic rocks. Spreading from the central point, or along the lines of eruption, they have produced plateau-like elevations, characteristic in every respect.

Richthofen says:† "Andesitic mountains are characterized by monotony in scenery. They form continuous ranges, which are often of considerable elevation and extent, but exhibit gentle outlines on their summits as well as on their slopes." This definition agrees closely with the region above indicated. It remains to be stated that the ranges are not formed by the andesite, strictly speaking, but summits and slopes of certain ridges have obtained their character from that rock. Relative

*Rep. U. S. Geol. Surv., 1873, p. 319.
†Mem. Cal. Ac. Sci., 1868, tom. i, part ii, p. 25.

to the overlying volcanics, the position of andesite, wherever it was recognized as such, remains constant. Frequently later flows of hot lava have passed over the already rigid andesitic mass, and have baked it very thoroughly. In this case the slabs of rock are often phonolitic, and show innumerable changes of color, produced by a comparatively large admixture of ferric oxygen compounds. As a type of the andesite of that region, we may regard that from Black Mountain. A dark-gray, almost black, micro-crystalline paste contains minute crystals of oligoclase. Rarely is the paste vesicular. Crystals of sanidite and a black mica (probably biotite) are distributed throughout the mass. Acicular crystals of hornblende are rare. Upon weathering, the thin slabs of rocks turn a reddish-brown, owing to further oxidation of the magnetite contained therein.

In the eastern portion of main volcanic mass, which includes the Uncompahgre group, a number of andesitic outcrops were noticed. As might be expected, the phonolitic character of andesite is restricted to mainly the upper horizon. It is owing, as can readily here be observed, to a reheating by the subsequently-arriving trachytes. On the north side of Saguache Creek this feature is especially noticeable. Long-continued, regular bluffs of trachyte overlie the andesites, and near the junction of the two the fragments of the latter produce a submetallic sound when struck. Here, too, as at many other localities, the andesites are accompanied by a series of tuffs.

All eruptions of andesite are purely *massive*. No truly *volcanic* eruption has been observed in Colorado, but others, less massive than those of andesite, of a peculiar type, occur frequently. In speaking of the trachytes, more particular mention will be made of the types of eruption and of the various ways in which they manifest themselves.

TRACHYTE.

It is the group of trachytes, above all others, that claims our attention. Not only are the varieties presented very numerous, but also the modes of appearance. Independent of the chronological successions, we can appropriately divide volcanic eruptives in accordance with their methods of protrusion. Such a division will not only furnish a clue as to the general appearance of the volcanic rocks, but also—after their character has once been recognized—to their geological age.

The distinction between massive and volcanic eruptions has long since been made, but it is inadequate to express all the most typical forms that will be observed. Five types of volcanic eruptions may be distinguished:

Massive, denoting the fact that the lava was poured out through one or more great fissures or openings, and upon reaching the surface immediately spread in every available direction.

Volcanic eruptions are such where the lava was propelled outward through a cylindrical tube or narrow fissure. Incident upon this method of eruption is the gradual formation of a crater and its accessories.

Isolated eruptions may be characterized as such where the lava issued from one or more openings, flowed slowly, and succeeded in building up a mountain or group of mountains. No indication of craters or other features of the volcanoes of the present day are noticeable.

Anarhactic * eruptions are those comprising one or more dikes or a dike-system. Narrow, sometimes long, fissures are formed in various

* I have coined this word in lieu of one expressing the main characteristics of the group it designates.—E.

rocks and strata by plutonic or volcanic seismic action. Lava is injected into these fissures presenting, eventually, the most typical appearance. Belonging to this group are the—

Intrusive eruptions. These latter are distinguished from the former by their relative position to the rocks adjoining. An anarhactic eruptive will usually be so located as to stand at approximately right angles to the stratification or structural planes of the formations it traverses. In case it becomes intrusive, however, which only can occur in sedimentary or in stratified beds, the foreign material will appear as one of the members, will be in part conformable with them, and partake of their various inclinations and deviations.

Scattering eruptives comprehend groups of small, isolated volcanics. They are intimately related as regards genesis and age, but appear as studding, mostly, one of the younger sedimentary formations.

These divisions will not be found to apply to all the sub-groups of trachytic rocks. Some of them show one or the other feature only. The subjoined groups of the entire trachyte series are based mainly upon the observations made in the San Juan Mountains. I first proposed it two years ago* and have since found the classification corroborated wherever I have met with the group. In case we have before us an anarhactic occurrence, it becomes a matter of difficulty to decide to which subgroup of trachyte it should be referred. unless it is in direct connection. Lithological characteristics alone will not always suffice to admit of final discrimination. It seems highly probable that many of the dikes and dike-systems we observe, though but a short distance removed from the trachorheites would most probably correctly be regarded as much younger.

Trachyte No. 1.†—The rocks belonging to this group may be regarded as accessories. In the southern edge of South Park they were first noticed, in connection with the andesites.‡ I have characterized the occurrence there as andesitic tuff. But few localities were found before 1874 which furnished satisfactory opportunities for comparison and study of this group. As soon as they were found, however, it became apparent that the tuff belonged, most properly, to the trachytic series. I am inclined to the opinion that the tuffs were ejected after the cessation of andesitic eruptions, and immediately preceded those of the trachytes. In its generic character the trachyte No. 1 forms a peculiar group. Although not fully answering the requirement of what has been described as an isolated group, it possesses many of them.

Essentially the members of this group are composed of what the Italian calls *lapilli*, of finely separated volcanic ash and fragmentary portions. Almost every volcanic eruption of the present day is either preceded or followed by an ejection of "ashy" material from the crater. The fate of Pompeii and Herculaneum show to what an enormous extent these ash-eruptions can increase even within the historical period. I regard, therefore, the ash-accumulations observed in the same horizon, at so many localities, as the beginning of the trachytic series.

Inasmuch as the ejections of ash and tuff takes place sporadically, and as the material has not that nature which allows it to spread over any considerable area, it will be found that the trachyte No. 1 is found only in isolated patches. Its horizon in the vertical scale is well established and constant, but its horizontal distribution is more or less accidental. A number of typical localities were observed both in 1873 and

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* Bull. U. S. Geol. Surv., No. 3, second series, May 15, 1875, p. 151.
† Rep. U. S. Geol. Surv., 1874, p. 195.
‡ Rep. U. S. Geol. Surv., 1873, p. 320.

1874. Among the most prominent are the deposits south of Black Mountains, east of the junction of Coochetopa and Tomichi Creeks, on White Earth Creek, and along the Rio Grande. Perhaps the most extensive mass of this material occurs on White Earth, and as the name is at the same time a descriptive one, I shall term the trachyte No. 1 the *White Earth group.*

An average thickness of about 800 feet may be accepted for this group throughout the San Juan country. It is readily recognized by the striking colors it exhibits. Most frequently white, gray, and yellowish colors predominate, but pink, green, brown, and even black are not wanting. Upon first glance the tuffs composing this group represent variegated marls. More or less frequently hard interstrata are contained therein, in that case producing terraces upon weathering. Generally, the material composing trachyte No. 1, is a light-colored feldspathic aggregate, loosely cemented. At some localities bowlders and fragments are found inclosed, giving the beds the appearance of a breccia. Minute crystals of sanidite, hornblende, magnetite, obsidian, and sometimes oligoclase are found in the tuffs. On account of their readily-yielding physical constitution they are rapidly attacked and worn away by erosive agents. Water-courses, wind, and other causes carve out most peculiar shapes from the gradually disappearing soft bluffs. Hard interstrata may give rise to the formation of "monuments." Toward the top of the series not infrequently thin beds of a hard, brown trachyte are interbedded into the tuffs. Succeeding flows of lava have thoroughly baked them and they now are hard, brittle, almost jaspery in their appearance. Here, too, we may often find concretions and nodules of various-colored jasper and of semi-opal. These two minerals cannot be regarded as characteristic of the White Earth group only, as they occur frequently higher up.

About three miles south of Black Mountain these tuffs were found, resting upon the andesite of that region. The tuff here shows a thickness of about 200 feet, is white, yellow to pink, greenish, and even brown. Several ravines have been washed into the loosely-cemented material, and their sides are studded with a variety of grotesque forms, the result of erosion. Toward the base the tuff becomes more compact, is gray, and closely resembles a very coarse-grained sandstone. True to the rule, this is only a local deposit. Soon the tuffs thin out toward the edges, and either disappear altogether, or are covered by younger rhyolitic eruptions. From a section taken in the course of north 80° east,* the relative position of the tuffs may be seen. No doubt the eruption which gave rise to the formation of Black Mountain occurred not from it, if not the main point of outflow was directly there. From there the lava flowed in a southerly direction. This same course was also taken by the tuffs. Outside of the main volcanic group the tuffs of this period do not often appear. They seem to be replaced at some points by breccias, but these do not bear the same relations to older and younger volcanics as the tuffs. In Wet Mountain Valley a few occurrences of tuffs were noticed, but they are of no importance.

Near the junction of the Cochetopa and Tomichi Creeks a comparatively large mass of andesitic tuffs belonging to this group are found.† White and yellow tuffs cover Middle Cretaceous shales and are in turn covered by sanidinitic trachytes. Erosion has dealt with the tuffs in the usual manner. Here, too, the horizontal extent of the tuffs is not very great. They have, no doubt, succeeded the eruptions farther east,

* Rep. U. S. Geol. Surv., 1873, p. 311.

† Rep. U. S. Geol. Surv., 1873, p. 345.

and have, in turn, been covered by the enormous masses of lava coming from the southwest.

One of the most typical occurrences is found on White Earth Creek.* The tuffs are of white, gray, and yellowish colors, disintegrating very readily. It is, perhaps, softer here than at most other localities, and for this reason does not exhibit the usual picturesque products of erosion. Farther northward, in Dr. Peale's district, the tuffs either do not continue or they are covered by younger members of the trachorheitic division. Inasmuch as granite is exposed along the Gunnison, north of White Earth Creek, the former view is probably the correct one. The extent of the tuffs on the White Earth could not be determined, as the trachytes above them obscured everything.

Two localities along the Rio Grande show a good development of the White Earth group. At the junction of Lost Trail Creek with the Rio Grande, we find a highly typical exposure.† Bluffs nearly 900 feet high show the outward characteristics of variegated marls. Upon examination they prove to consist of trachytic tuff. A striking feature is the marked, apparent stratification. This, however, is not due to consecutive strata in the proper sense of the word, but is owing to accumulations of coloring material within certain horizontal zones. Magnetite is dispersed throughout the entire mass of the tuffs, and it is, primarily, this that produces a number of colors. Different stages of oxidation manifest themselves by different colors. Thus are produced various shades of yellow, orange, brown, and green. Westward the tuffs extend beyond Pole Creek, but are mostly hidden from sight by trachyte. On Pole Creek they once more crop out, and it may be observed that they are harder, more compact, than farther east.

Another locality where the tuffs appear is near Crooked Creek, at the head of Antelope Park. They differ in nothing from the others, and are of but small horizontal extent. Although the characteristics and appearance of this group within restricted areas are very constant, their occurrence is practically an accidental one, and they are not posessed of the same value in systematic classification as the younger members of the Trachorheite group.

An interesting occurrence was found north of Saguache Creek, near Rock Cliff Dairy. Between two andesitic hills a valley was in part filled with tuffs.‡ Only a slight accumulation was found, resting upon the andesites directly; the remainder seemed to overlie portions of a local Tertiary fresh-water deposit. Through this tuff a dike of porphyritic obsidian had found its way to the surface.§ The black obsidian, 15 feet in thickness, contrasts admirably with the bright yellow, greenish, and pink colors of the tuff. Numerous small fragments of the tuff are inclosed by the obsidian, and they are in this case thoroughly baked. In appearance they closely resemble jasper. For several feet on either side of the dike has this baking influence extended itself, until the heat of the molten obsidian was no longer able to melt and change the feldspathic tuffs. Small concretions of cloudy agate and semiopal occur at the borders of the dike. It seems uncalled for that siliceous concretions should occur so frequently near the junctions of two different volcanic rocks, neither of which contains free quartz elsewhere. From the constant form in which the quartz occurs—that of jasper and semiopals mostly, less frequently of chalcedony and agate—I am led to the inference that the silica may have been brought forth in a hydrated condition, together with the younger erupted material.

* Rep. U. S. Geol. Surv., 1874, p. 202.
† Rep. U. S. Geol. Surv., 1874, p. 201.
‡ Rep. U. S. Geol. Surv., 1873, p. 344.
§ Ibidem, p. 345.

In that case rapid cooling would probably prevent its entering into any composition which otherwise might have been effected. Thus, too, does it seem easily explained why so often semiopal (quartz containing water) should be found in such relative position. As will be seen farther on, the question of hydration is a very important one in discussing the origin and primary condition of volcanics. Therefore, any occurrence typical and frequently repeated, will add its share to the solution of an otherwise comparatively intangible question. The obsidian, too, of this locality shows special features of interest. The mineral is black and contains small crystals of sanidite, thus becoming porphyritic. Its structure is concentric at several places. Within the dike we find a spherulitic, concentric arrangement of the obsidian. From small spheroids they are found to the size of 10 feet in diameter. Similar concretions have been noticed elsewhere in volcanic rocks. One of the best known is the occurrence near Teplitz, in Bohemia. There a concentric arrangement is observed in the porphyries.*

Trachyte No. 2.†—Less varied in its lithological features than the former group, this one presents a very uniform appearance. Compared with No. 1 and the succeeding No. 3, this group does not present such marked characteristics as the other two. The rocks are by far harder and more compact than those of the preceding group, and they are better able to withstand erosive agents. Weathering into comparatively small fragments of a light-brown color, this trachyte generally presents gently-rounded slopes near the base of bluffs or mountains. Easily decomposed, it furnishes soil, and an ample, unbroken vegetation not unfrequently denotes its presence. Exceptions from this rule are not wanting, however. Trachyte No. 2 is found chiefly along the main drainage of the San Juan Mountains. Taken as a whole, the vertical as well as horizontal arrangement of the volcanics in that region is extremely regular. We find, therefore, that in its greatest depressions the lower beds and groups are mostly exposed. Great uniformity of petrographic character will be found to exist in the members of this group. As a rule the paste is microcrystalline, slightly vesicular or compact. Numerous small crystals of sanidite are dispersed throughout, associated with diminutive crystals of black mica. Prisms of hornblende, dark-green to black, occur sparingly. When freshly broken the color of the rock is bright-pink, with a blueish tinge, or reddish-brown. Upon exposure it soon becomes dull. Toward the top of the group nodules and bands of porphyritic pitch-stone and obsidian set in. They are characteristic of this group, and almost entirely confined to it. A total thickness of about 1,200 feet may be accepted as the average for this group. On account of its topographical position, I shall distinguish trachyte No. 2 as the "River group." Its position along the borders of the main streams of the San Juan region justifies the name.

Although in no direct connection whatever, I am inclined to regard the trachytes of the eastern portion of Colorado as belonging to this group. Certainly their relative position to the andesites and tuffs assigns to them this place. Lithologically, also, they agree very well with the characteristics exhibited by the group elsewhere. It is natural that an intervening space, devoid of volcanics, so large as the one in this particular instance, should lead us to expect considerable changes in the groups that must be regarded as belonging together. In its physical character, No. 2 belongs to that type which has been designated as massive eruptive.

* Cotta, Geologische Bilder, Leipzig, 1871, p. 1. † Rep. U. S. Geol. Surv., 1874, p. 196.

On the higher portions of the mountainous region lying to the westward of Pike's Peak we find trachytes that are referable to this group. They are generally found superincumbent upon the andesites or tuffs. Regular stratification is shown, indicative of the regularity of the flows. It may be observed that the upper portions of each flow or stratum have been remelted or baked by succeeding flows of hot lava. In color, mineralogical composition, and physical features, these occurrences agree very well with the characteristic of the western rocks belonging to the same group. Not only do we find them in the formerly continuous series of volcanics of this region, but they may also be observed in connection with smaller local massive outflows. East of Wet Mountain Valley, toward the Greenhorn Range, a large portion of the metamorphics are covered by such trachyte. Local outcrops occur at various points along the Arkansas River, along the southern and southwestern edge of South Park, and in the southern portions of the Sawatch Range.

In the region of the San Juan Mountains the River group is admirably well-developed. It is in sight at all those points at which the tuffs have been mentioned, and overlies them uniformly. Along the Rio Grande we have occasion to study the River group most effectually. Disruption of the volcanic strata has there produced a number of vertical or very steep bluffs. On their faces we notice a very uniform appearance of the rock and the characteristic obsidianitic inclosures near the top. Throughout the entire district No. 2 can be traced, always occupying the same relative position. An astonishing regularity of the flows can be observed, and it is possible to follow the same unbroken stratum sometimes for nearly 50 miles. This feature indicates the grand scale upon which the volcanic eruptions of the region occurred. Southward, throughout the extension of the San Juan Mountains the River group appears near the base of the mountains. It there totally obscures any of the tuffs that may occur. Few of the streams within the main mountain-mass cut down low enough to expose this trachyte, and we therefore find it almost exclusively along the edge. Owing to a constant, though gentle, easterly dip of the stratoid flows, No. 2 no longer can be found on the eastern border of the range, but is confined to the western. Its character is uniform throughout.

Following the course of the Rio Grande, we find a full development of the River group at Wagon-Wheel Gap. The total thickness there is about 1,200 feet.* In the lower portions of No. 2 numerous inclosures of jasper, chalcedony, and agate occur. Many fragments of these may be found on the south side of the gap. Toward the northeastern and northern border of the volcanic area these trachytes continue. They form some of the low rounded bluffs along Saguache Creek, and, extending beyond the Los Pinos agency, are found fully developed again on White Earth Creek. Wherever favorable opportunities were afforded, plateaus are formed, in receding terraces, by the members of this and the next higher group. North and west of my district Dr. Peale has found the continuation of the River group in his district.†

Although evidences of forcible disturbances are not wanting in this group, they are not so numerous nor so characteristic as higher up. Wagon-Wheel Gap affords one of the most striking examples of this kind. There a hill, located transversely to the course of the Rio Grande, has been rent asunder, and the river has found its way through it. Columnoid structure of the upper portions of the trachyte may have

* Rep. U. S. Geol. Surv., 1875, p. 154.

† Ibidem, p. 93.

facilitated the disruption, which seems rather difficult of explanation. Seismic action, in preference to any other, may be regarded as the cause. It will be noticed that mineralized springs not unfrequently occur in this number of the trachyte. Its comparatively ready decomposition and its usual orographic position explain this feature. The most prominent among them are the hot springs of Wagon-Wheel Gap.*

As occupying a position between trachytes No. 2 and No. 3, we may regard the trachytic breccia or conglomerates. It is evident that the horizontal distribution of this conglomerate must necessarily be, to a certain extent, commensurate with the distribution of the volcanics. In 1874 I found but few localities where the conglomerate was exposed. Altogether our explorations were carried on too much within the mountains to show us the former shores of the volcanic land. Dr. Peale† found the conglomerates covering an extensive area north of the Gunnison River. This is the northerly continuation from the main San Juan group of volcanics. He found the conglomerates overlying Cretaceous beds, and covered, in turn, by rhyolite. Inasmuch as the inner limits of the conglomerates must be regarded as the shore-lines of the ancient volcanic land, its distribution becomes a matter of importance. Certainly large quantities of the readily-disintegrated material have been removed from their original places of deposition, and, in consequence, the exact limits cannot be accurately drawn. Essentially, as is seen from the occurrence of the conglomerates, the volcanic land had at one time the same general shape that the entire area shows at present. Eastward of the conglomeritic beds found by Dr. Peale, they seem to disappear. No connection was observed between the group north of the Gunnison and the one appearing a short distance north of Del Norte.‡ Along the eastern edge of the San Juan Mountains the conglomerates appear in the deep cañons of the Rio Grande drainage. On the Conejos particularly the walls have been carved into fantastical shapes out of the soft material. It will be remembered that the volcanic mountain area becomes narrow as we reach a locality as far south as Rio San Antonio. West of the headwaters of this stream the connection of the conglomerates of the two sides is almost accomplished. Along the entire western border of the mountains we find the conglomerate again. It occupies an absolutely higher position than farther east, owing to the easterly dip of the volcanic strata. Near the Rio Grande Pyramid it is lost. Again it appears on the drainage of the San Miguel and of the Uncompahgre.§

In thickness this conglomerate shows considerable variation when distant points are compared. Near the Rio Grande Pyramid the thickness is about 200 feet. As we proceed southward along the western base of the mountains, it increases considerably. At Pagosa Peak we find it to be 1,200 feet, and on the headwaters of Rio Navajo about 1,500. Crossing over to the eastern slope of the range, and examining as we proceed northward, the same conditions are apparent. On the Conejos the thickness of the conglomerates is about 1,200 feet, on the Alamosa 700, and north of Del Norte about 300. North of the Gunnison River Dr. Peale has found the thickness of the breccia to be 400 feet. At no other locality in Colorado, except in connection with the main San Juan volcanic group, was this breccia observed. Its existence is owing

* Rep. U. S. Geol. Surv., 1875, p. 154; Rep. Expl. and Surv. west 100th Mer., vol. iii, 1875, p. 623.
† Rep. U. S. Geol. Surv., 1874, p. 170.
‡ Rep. U. S. Geol. Surv., 1875, p. 1853.
§ Rep. U. S. Geol. Surv., 1875, p. 94.

to what may be regarded as an incidental cause, and its accompaniment of trachyte No. 2 is not an invariable occurrence. Dependent upon favorable orographic and hypsometric conditions, it has been deposited in varying masses along the border of the former volcanic peninsula. There is scarcely any doubt that the waters into which the conglomerate was deposited occupied but a restricted area as compared to that covered by immediately preceding formations. After the ejection of the lava which composes the flows of the River group, a peripherical subsidence probably took place, permitting the accumulation of water along the borders of the volcanics. I have not enumerated the conglomerates as an independent group in the list of volcanics of Colorado. This omission has been made, because I regard its presence and its development as essentially accidental. Very few extensive groups, indeed, of volcanics occur anywhere without being accompanied, more or less, by tuffs and breccias or conglomerates.

Structurally the conglomerates present the usual type. At some localities a separation of the coarse from the fine material was observed. Not unfrequently "bands" seem to occur in the conglomeritic walls, often continuing and visible for a long distance. Upon examination, these bands prove to be of different physical composition. Mostly they are composed of more uniform (in size) finely-separated material, which is either cemented together more loosely or more firmly than the surrounding masses.

An examination of the lithological character of the bowlders contained in the conglomerates shows that we have before us the larger quantity as resembling the trachytes of No. 2. Higher up, near the upper termination of the breccia, different rocks set in, however. Some of them closely resemble the porphyritic trachytes, others can scarcely be found to differ from types that we find in the younger groups of the trachorheitic series. I am inclined to the opinion that local eruptions took place during that period of time when the main volcanic group was nearly surrounded by water, and that they furnished the material for this rare species of conglomerate. At a number of localities evidence remains of the deposition of the breccia into water. Dr. Peale has noticed* its "stratified appearance," and along the western border of the mountains such evidence was frequently observed.† Near Station 36 of 1875 a layer, irregular in its vertical dimensions, of pumice was noticed near the top of the conglomerates. Upon investigation it proved to have been, originally, obsidian, which flowed into the water receiving the breccia.

Characteristics not only of physical composition, but also of physical appearance, are exhibited by the conglomerates. As a rule, they are soft, easily eroded, readily cut by flowing water. This, in connection with the irregular distribution of bowlders and softer portions, is productive of very marked results. Water, wind, and frost carve the most fantastic figures out of the yielding material. Steep, frequently vertical, bluffs are ornamented by many varieties of forms. Caves and arches are formed, the former not seldom affording shelter to some of the wild animals infesting the region. In case the breccia be firmly cemented, these detail-features will, in a great measure, be lost. Steep walls, either as bluffs or in cañons, with but scattering monumental ornamentation, characterize the harder varieties of the rock. Throughout the volcanic area, wherever the conglomerates were observed, these characteristics were found to hold good. By their aid this group can readily be dis-

* Rep. U. S. Geol. Surv., 1873, p. 94.
† Compare Rep. U. S. Geol. Surv., 1875, p. 213.

tinguished, even from long distances. Adding the more or less horizontal arrangement of its beds, we find the conglomerates to be one of the most conspicuous groups of the entire volcanic series.

Trachyte No. 3.*—This subdivision I have separated into two groups, No. 3 *lower* and *upper*. The distinction was made not only on account of lithological, but also for orographic reasons. No. 3 may be regarded as the most widely extended of the trachytic series. Wherever the River group, by virtue of the dip of the flows, has disappeared from sight, there we find No. 3 in the lower portions of the region. Forming prominent, characteristic bluffs, with steep faces, it may at once be distinguished from the preceding number by its darker color. Offset by the conglomerates, wherever they appear, it sharply marks its own horizon. In the interior of the main volcanic area it is generally found high up, as the lower positions are monopolized by the older groups.

No. 3 lower is recognizable by its physical appearance. Almost always it forms steep slopes. When found in the valleys it incloses them with precipitous walls. A tendency to columnar structure adds greatly to this feature. Lithologically it is also distinct. When freshly broken the specimens show a reddish-brown color, but are dark-brown upon weathering. Toward the top of No. 3 lower some lilac-colored beds set in, but they are of inferior thickness. Numerous small crystals of sanidite occur in the brown paste. This is sometimes compact, sometimes slightly vesicular. Mica (biotite) is found sparingly. It is black when fresh, splendent bronze-color after exposure. When forming the slopes of mountains the rocks of this group generally weather in slabs or angular fragments. Cases of reheating and baking may be observed comparatively rarely only. For this lower group a thickness of 800 to 1,000 feet was accepted, wherever fully developed.

No. 3 upper is lighter colored throughout. The paste is a grayish-red or brown and lilac or pink. Less sanidite is found in this group than in the lower one, but more mica. Hornblende crystals occur as accessory mineral. Toward the top of the group a series of beds occur that I have characterized as "a feldspathic matrix without any segregated minerals."† In color they contrast strongly with the underlying group. They are either white, light yellow, gray, greenish, or pink. About 400 feet may be regarded as the maximum thickness of this series. Although found at a number of places, their occurrence is not constant throughout. It may be that they owe their existence to local outflows, or perhaps they were primarily distributed over but a small area. The connection has been obliterated by erosion and other causes. Within these beds pitch-stones, mostly porphyritic, sometimes occur. A local conglomerate occurs near the top of No. 3 in the vicinity of the Rio Grande Pyramid, both west and north of it. It stands in no connection with the main conglomerate, but closely resembles it in its essential features. Two hundred feet may be regarded as its maximum thickness. For No. 3 upper we can assume a total thickness of 1,000 to 1,500 feet. Variations in thickness frequently take place, rarely involving more, however, than a few hundreds of feet. More disturbances of the original position of the beds have affected this group than either of the preceding. From the characteristic position occupied by the members of this group near the edges of the main volcanic area, and from the striking appearance the strata there presents, I term it the "Bluff group."

In case the volcanic beds are alternately hard and soft, we will ob-

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* Report U. S. Geol. Surv., 1874, p 196.

† Rep. U. S. Geol. Surv., 1874, p. 200.

serve the hills to be terraced. Near Saguache this is very well illustrated.*

For the appearance of the members belonging to trachyte No. 3 we must look mainly along the northern and eastern border of the mountains, in the interior and in their southern extension. Regarding the San Juan Mountains from the stand-point of a geographer, we must separate them essentially into two divisions; the Uncompahgre group and the San Juan Mountains proper. These latter I have regarded, in the Annual Report for 1875, as the southern extension of the Sawatch Range. Strictly speaking, they may be considered so. The term "San Juan Mountains" is one, however, so well known, and so indiscriminately applied, that it may be well to retain the name, but restrict its application. While the Uncompahgre group is certainly a very typical arrangement of the most rugged mountains, without order or system, the southern continuation of the entire mountain-mass is definable as a range. It is to this that I apply the name of San Juan Range. Taking a comprehensive view of it, we find it to be a narrow, elevated plateau. Streams and other agents have deeply furrowed it, but the main summits retain a uniform elevation. In harmonious relation with the rocks and beds composing this range do its orographic features show themselves to stand.

While the most rugged group of mountains is composed mainly of trachyte No. 4, the San Juan Range owes its existence to the Bluff group. A short distance west and northwest we first find the members of No. 3 participating in the structures of small plateaus, hills, and bluffs. Reaching to elevation of 13,000 feet above sea-level, we find deposited the highest members of the group. Conformable with the underlying beds, in perfect accordance with the total arrangement of the volcanic flows, they frequently form the summits of some of the high peaks of that region. As we proceed westward, we find the absolute position of the beds of No. 3 to be higher. Partly an amplification of the strata accounts for this, partly the general easterly dip of all the volcanics of that section. The highest point is reached on the summit of Uncompahgre Peak, 14,235 feet. None of the flows belonging to this group appear to extend northward beyond the Gunnison River. There the conglomerates are covered by rhyolites.†

By far the greatest development of trachyte No. 3 is found in the San Juan Range. From the Rio Grande Pyramid we can trace the members of this group along the range to the southern border of Colorado. Forming frequently extensive plateaus that are but little lower than the highest peaks of the range, the flows present one unbroken series throughout. The gentle southeasterly dip is always noticeable. It is owing to this that no prominent peaks are found on the eastern slope of the range, while the western is amply supplied therewith. Strictly speaking, the western slope is but the abrupt termination of the plateau, while the eastern is essentially its sloping summit. Erosion and abrasion have necessarily had a degrading influence, so that now the slope is more than commensurate with the dip-angle of the volcanic beds. Whether the isolated peak on the summit of the range should be regarded as evidence of local eruptions or as the remaining portions of once continuous beds, seems difficult to determine. I accept the former view. Although I find scarcely any variation in the lithological character of the rocks, the flows of No. 3 are so uniform and continuous in their character, that I cannot regard them as having been ejected from

* Rep. U. S. Geol. Surv., 1873, p. 345.

† Rep. U. S. Geol. Surv., 1874, p. 170.

but very few places. Had large masses of lava, such as we now find in the range, issued from the numerous prominent peaks, we would scarcely observe the same uniformity that we now find. At the same time, the peaks in question do not at all exhibit the petrographic characteristics that we should expect them to show did they belong to a younger group of volcanics; *i. e.*, were they remnants of flows subsequent to those of No. 3.

At some of the highest localities of the range we meet with the hard variegated beds belonging to, and sometimes forming the top of, the Bluff group. On Banded Peak,* and farther south, they were noticed. Here their thickness reaches about 800 feet. I am inclined to think that a number of the upper beds of No. 3 occur in very much lighter colors, and have therefore been added in the variegated beds. Porphyritic pitch-stones and obsidians occur here also. A large bed of pitch-stone, varying from 4 to 15 feet in thickness, was found near the Rio Grande Pyramid in these strata and traced for the distance of about six miles.

North and west of the Quartzite Mountains No. 3 is gradually superseded by No. 4. It again appears, however, on the western and northwestern border of the volcanic area. Underlying the younger beds, it is mostly found at the base, hiding from sight the two older groups. In several instances cañons are cut down sufficiently deep to expose them, however. All of these older groups appear to thin out in that region, while the younger ones reach a very considerable vertical development.

Displacements of strata are comparatively frequent in this group. Two of the most prominent are those at Mount Sneffels and at Bristol Head. The former we have named, from its form, the Great Amphitheatre.† For the distance of 2,000 feet the strata have dropped down vertically, causing an oval depression about four miles in length and nearly a mile wide. On nearly all sides the walls are perfectly perpendicular. It seems probable that this "drop" and one near the Rio Grande Pyramid were caused by enormous caves. To all appearance they have occurred but recently, comparatively speaking. At the Great Amphitheater the strata, removed a distance of nearly half a mile from their original position, have retained a certain continuity to the present day. Although cracked and broken into innumerable fragments, the pieces, often weighing hundreds of tons, lie side by side, separated, not rarely, by only a narrow fissure. At Bristol Head‡ the cause of the displacement is more apparent. A small ridge, north of Antelope Park, runs parallel with the edge of the Bristol Head Plateau. Upon examination, it was found that the Rio Grande had probably undermined this portion by washing away a deposit of trachyte No. 1. Thus the weight could no longer be sustained, and the unsupported portion dropped down a vertical distance of more than 1,000 feet. The "drop" is not purely vertical; it was accompanied by a movement toward the south, away from the plateau with which the detached portion was originally in connection. A very pretty little valley, containing Lake Santa Maria, has thus been formed between the two steep, enclosing walls. Local "drops" of small dimensions occur quite frequently in the strata of the Bluff group. In its physical character this group belongs, as well as the preceding, to the massive volcanic eruptions.

Trachyte No. 4.§—Only during the summer of 1874 did I have occa-

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* Rep. U. S. Geol. Surv., 1875, page 167.

† Rep. U. S. Geol. Surv., 1874, page 206.

‡ Rep. U. S. Geol. Surv., 1874, page 199.

§ Rep. U. S. Geol. Surv., 1874, p. 196; Bulletin U. S. Geol. Surv. No. 3, second series, May 15, 1875, p. 152.

sion to study this series. So far as I am aware, no publication has been made with reference thereto since that time. The group is, horizontally, a restricted one, but fraught with the occurrences of the highest interest. Not only are the rocks themselves of very peculiar type for the position they occupy, but the presence of many metalliferous veins lends additional importance to the group. It occurs in the heart of the Uncompahgre group and extends to its western edge. Some of the highest mountains of that region are partly or wholly composed of it. The latest discoveries of ore-bearing veins seem to have been made at localities where this group occurs merely as capping the older ones. With other words, instead of the veins being confined to No. 4, they extend through it and can be reached in older formations.

On the point of petrographic character this group presents more variations than any one of the volcanics. Many brilliant colors, of the most delicate shades, are shown by the mountains and ridges. They are due to admixtures of certain mineral substances. Dark colors may be said to be characteristic of the main bulk of this group, but a very prominent exception is made by what I have termed the "*red stratum*."* Originally white, the presence of ferric oxygen compounds gradually changes this color to yellow, orange, red, and brown. The rock is a micro crystalline feldspathic paste of white color, containing very minute transparent crystals of sanidite and small crystals of pyrite. Throughout the district, wherever this stratum could be traced, the crystals of pyrite were contained in it as an "impregnation." Some of the largest cubes seen will hardly measure 0.5 millimetre on the edge. Decomposition of pyrite releases the sulphur and changes the iron from a bisulphide to hydrated sesquioxide. This, in varying percentages, produces the colors and shades above enumerated.

Stating the general mineralogical character of the rocks of this group, we may say that the paste is compact (rarely vesicular) and micro-crystalline. Oligoclase is the most prominent of the enclosed minerals. Another feldspar—triclinic, probably andesite—occurs with it. Sanidite may be regarded as an exception, and occurs only in the lower members of the group. Pyrite, magnetite, hornblende, mica, and chlorite are accessory minerals, of which the first-named occurs in the shape of an impregnation.

For trachyte No. 4 we can accept a thickness of 3,000 to 3,500 feet. In its lower members it retains the stratoid character very well, but higher up this is greatly obliterated. From the fact that this series forms the most rugged and typical mountains of the Uncompahgre group, I term it the "Mountain group."

Taking into consideration the general mineralogical constitution of the rocks and the existence of ore-bearing lodes, we are tempted to parallelize this group with propylite. This temptation has become all the greater since the discovery of tellurides of gold and silver in the Hodgkiss Lode of Lake district.

Richthofen places propylite at the base of the volcanic series in our Western Territories, and that position is accepted for it by all who have acquaintance with the regions involved. It is merely for the purpose of anticipating any comparisons that might be made, and to justify the position I have assigned this group, that I enter into a brief discussion.

It is well known that the lodes of Transylvania are found in a "*greenstone trachyte*." This rock has been referred to the "trachytic series"

*Bull. U. S. Geol. Surv. No. 3, second series, 1875, p. 154; Rep. U. S. Geol. Surv., 1874, p. 230.

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by most European geologists. The term "trachyte" was there by no means so limited as might have been desired, but comprised a number of distinct rock-species, or even genera. Bielz proposed for this rock the name of timazite. Cotta* states that where he saw it it was decomposed, "frequently bleached almost white, commonly containing pyrite disseminated through it." At Nagyag and Offenbanya the ore-bearing rock is the timazite. This is synonymous with Richthofen's propylite. Were it not for the fact that we have a direct contact between the older trachytic rocks and the ore-bearing group of the San Juan region, the mineralogical and petrographic similarities of the two would probably lead to its identification as propylite. One of the most favorable localities to study the relations of the Mountain group to those underlying, is found near the headwaters of the Rio Grande. Distinct stratification of the lower members of No. 4 is noticeable. There they rest directly and conformably upon the upper strata of No. 3. This feature may distinctly be traced all along the line of junction. At the time the trachytes of No. 4 were ejected the region where now the mines are located was already considerably corrugated. A ridge extended northward from the Quartzite Mountains, which barred the progress of No. 3. The succeeding flows, however, utilized the equalization of *niveau*, and, passing over this ridge, penetrated beyond it. Evidence of this ancient ridge may be found in Arrastra and Cunningham Gulches and on the elevated plateau east of them. This fact accounts for the absence of the three lower trachytic groups along that entire border of the volcanic area containing the headwaters of the Animas and San Miguel Rivers. Although, consequently, the ore-bearing rocks of the San Juan region appear as almost an isolated group, they are in reality in direct and harmonious connection with the older groups of the trachytic division. In the direction of Mount Sneffels and Uncompahgre Peak this connection can more readily be found, and will be clearly understood.

At the time of my visit the region had not even been thoroughly prospected. Subsequent discoveries made since those in and near Baker's Park, mostly occur within the limits assigned to the Mountain group. As significant I regard the presence of the "red stratum." I do not mean to insinuate that such localities that do not exhibit it will be found barren of ore, but I am of the opinion that the bountiful mineral impregnation with which this group is supplied, indicates the former existence of such causes as led to the formation of minerals that are classed as "ores."

Wherever any definite structure can be observed in the rocks of No. 4, it will be found to correspond with that of underlying volcanic rocks. As it is the last one of the series showing such character, I have included it under trachyte, and have closed the trachytic division with it.

No members of the Mountain group were found in the San Juan Range. Their southern border is immediately south of Sultan Mountain, where they unconformably overlie Carboniferous sedimentary beds.† From there it swings around to the headwaters of the San Miguel and follows the edge of the mountains northward beyond Mount Sneffels. Between Mount Sneffels and Uncompahgre Peak the limits of the Mountain group turn eastward. They include within their area the Station 12 group, and, after having crossed the Rio Grande, disappear a short distance south and east of Silverton. At this latter locality they become thin, overlying metamorphic, Devonian, and, in part, Carboniferous rocks. In Cunningham Gulch the metamorphics, chloritic schists,

* Ore-deposits, p. 277

†Rep. U. S. Geol. Surv., 1874, p. 217, section II.

crop out, and in Arrastra Gulch they have been reached by the Little Giant Mine. Within the Station 12 group we find a very excellent development of the red stratum. Again it is observed at Mount Canby, near the junction of Pole Creek with the Rio Grande. On Bear Creek, west of Baker's Park and along Mineral Creek we find it well represented. Near Mount Sneffels the evident stratification of the volcanic rocks can be most satisfactorily observed, and a connection can from there be established of trachyte No. 3 eastward to the Rio Grande. At Handie's Peak and other localities we noticed a large number of very regular quartz veins. Since our visit many of them have been "located," and some are worked.

In Bulletin No. 3, second series, and in United States Geological Report for 1874, a discussion of the San Juan mines may be found. It is needless, therefore, to repeat any information there contained. Nearly all of the lodes located near Baker's Park were found in trachyte No. 4. Subsequent investigation has shown that they penetrate beyond the lower limits of this group, and, without any appreciable change of course or character, enter the metamorphics, which are covered by the trachyte. All the veins that I had occasion to visit, located within the trachyte, were argentiferous. The only one which was at that time worked in the underlying schists, the Little Giant, is auriferous. I am not aware whether this feature has since been established as the rule. Mining is not unfrequently carried on in a very desultory manner in our western country, and it is very difficult to obtain any reliable data, except by personal inspection. A surprising regularity of the metalliferous veins may be observed. I know of no place where the veins appear so undisguised on the surface. A photograph taken at Howardsville has been reproduced.* For a vertical distance of about 1,400 feet we can trace the veins of this hill-side.

As to the cause which produced the formation of the fissures which we now find filled with metalliferous matter, several suggestions may be offered.

First. They may have been produced by the contraction of the volcanic masses upon cooling.

Second. Subsidences of certain portions may have given rise to the formation of fissure-systems.

Third. They may owe their existence to plutonic or volcanic seismic action.

We notice that nearly all the veins have a strike lying between north 45° west, and north 45° east. This indicates a common cause for their formation. Generally the fissures will be found nearly at right angles with the beds or flows of trachyte.

The fact that the veins enter the underlying metamorphic rocks, and do so without changing their character, excludes the first proposition. No doubt the irresistible force of contraction would probably have succeeded in carrying the fissure downward into the harder, metamorphic rocks. In case this had occurred, however, the fissures would have changed their character. Slides would either have occurred, or the veins must grow narrower with increasing depth. Neither of these instances was observed.

If subsidences had occurred after the established rigidity of the volcanic rocks, it would be shown in their stratification. Declinations of some extent, or faulting, must have taken place.

In preference, I accept the third explanation, not only for these but

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* Rep. U. S. Geol. Surv., 1874, p. 232.

for nearly all vein systems. If we have, so near the place of lode-occurrences, the agents which can and undoubtedly have produced violent seismic action, we will rarely go amiss in assigning to them the cause of producing such fissures. Not far distant from the lode-bearing locality we have evidence that younger, more recent eruptions must have taken place. I allude to such instances as the Mount Wilson group, the isolated volcanic groups near the headwaters of the Dolores, and to the enormous quantities of basaltic lava that have been ejected northeast and east of the mining districts. Accompanying the eruptions, the usual phenomena are fully adequate to have produced the effects we now observe.

In previous pages the impregnation of the red stratum by pyrite has been mentioned. This mineral was probably segregated during the period of the cooling of the rock. Its presence denotes nothing save the existence and ejection of a large amount of iron and sulphur at the time of eruption. Such conditions, also, must have prevailed, as were favorable to the combination of this metal and metalloid. In case, therefore, if this mineral, or rather its component parts were drawn from the same source that furnished the trachytes, it may justly be presumed, that the resources were not thereby exhausted. Inasmuch as the red stratum is one of the older members of the mountain group, it may be inferred that its source lay nearer the surface of the earth than that of the succeeding flows. Assuming that the fissures, either as such, or in ramifications and other forms reach downward to this source, or approximately to it, we may explain the filling of the fissures with metalliferous and other matter. Infiltration, in its widest sense, has no doubt produced the ores as we now find them in veins. Whether such infiltration occurred by the means of mineral substances in solution or in a state of volatilization cannot always be determined. In this instance we have a case where, perhaps, both methods were employed. From the vertical distribution of minerals in the vein much can be learned, and, no doubt, future developments of the San Juan mines will furnish many data of the highest interest and value.

Special features of trachytic rocks.—Some very peculiar effects of erosion were observed in the trachytic rocks. The fantastic forms generally exhibited by members of the White Earth group and the conglomerates have been mentioned above. A very striking instance of the former was found on a small creek flowing into Henssen's Creek.* On the steep slope of a hill an accumulation of tuffs had taken place. Basaltic bowlders have rolled down upon the hillside from the edge of a plateau and have lodged there. Temporary streams and other aqueous erosion carved out columnar "monuments," each one surmounted by an erratic bowlder of basalt. Their height is 20 to 30 feet.

On South River, which joins the Rio Grande a short distance below Antelope Park, a unique group of similar monuments was discovered.† They have been carved directly out of the conglomerate which reaches a thickness of about 600 feet at that locality. Some of the large bowlders of the conglomerate act as protecting caps and have preserved the slender columns supporting them from destruction. Thousands of these monuments are crowded into a small space, that for its unique beauty surpasses any other spot in Colorado. While we are accustomed to see these monuments—at best—30 feet high, they here rise to the towering dimensions of 400 feet. Arches‡ and caves are found at the same locality, remarkable for their regularity and symmetry of form.

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* Rep. U. S. Geol. Surv., 1874, p. 195.
† Rep. U. S. Geol. Surv., 1875, p. 156.
‡ Ibid., p. 158.

Near Mount Wilson a slender, trachytic monolith attracted our attention.* Upon a steep base we find an obelisk-shaped rock, 290 feet in height. The tendency to columnar structure of the rocks composing trachyte No. 3 has been noted above. It is owing to this that the rock "Lizard's Head" has been able to form itself. It is but the remnant of an extended flow, all other portions of which have disappeared under the destructive hands of erosion and decomposition.

RHYOLITE.

With rhyolite I close the main group of trachorheites. Although lithologically readily distinguished from the preceding members, it does not offer points sufficiently characteristic generally to admit of separation in hurried field-work. It may be stated that, as a rule, rhyolite is intimately associated with the older trachorheites. Exceptions, however, are not wanting. Dependent upon its associations, the character of the rock is such as to be classed among either massive, intrusive, or anarhactic eruptives. In the first instance we find it together with trachyte; in the second it usually accompanies older volcanic rocks, and in the third it may be observed at many points, without being in any direct connection with other formations of similar genesis.

At no point in Colorado were very extensive masses of rhyolite observed. It occurs together with the trachorheites of the Front range, in the Elk Mountains, in South Park, and in the Uncompahgre Mountains. Frequently the connection with trachyte, both as regards position and petrographic character, is so intimate that the question may arise, whether or not we have before us simply a changed trachyte instead of a specifically distinct rock species.

Perhaps the most distinguishing feature of rhyolite, as compared with other volcanics, may be found in the presence of free silica. This occurs, when visible, in the shape of small fragments, grains, or crystals. Not unfrequently, however, it appears in none of these forms, and then only the microscope or analysis can reveal the species of the rock. In general habitat the resemblance of rhyolite to the various trachytes is so great that unless free, visible silica be present, mistakes can readily occur.

Throughout Colorado we find rhyolite. At no place does it show itself in large masses, but appears usually of subordinate importance in connection with other eruptives. In order to present a general idea as to the form in which it is most frequently met with, I shall discuss, first, the massive, then intrusive, and finally anarhactic eruptions of this rock. All of these are of great interest, and are important at the regions where they occur. Intimately associated with other groups and formations, the rhyolites comprise a prominent chapter in the geological history of the State.

Massive.—Flows of rhyolite, rather limited in extent, may be noticed near the Front range, south of Black Mountains.† It there forms low bluffs, skirting the base of the mountain. These are superimposed, in part, on trachyte and tuffs; in part, on Carboniferous strata. South of the Arkansas River, west of Wet Mountain Valley, is the Rosita mining district. There again we find rhyolite. Its horizontal extent is not considerable. At that locality the rhyolite rests directly on granite. Ore-bearing veins traverse both these rocks.‡ No change can be noticed in the characteristics of the lodes upon leaving the granite

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* Rep. U. S. Geol. Surv., 1874, p. 207. † Rep. U. S. Geol. Surv., 1873, p. 360.
‡ Rep. U. S. Geol. Surv., 1873, p. 331.

and entering the younger volcanic rocks. An analogous case occurs in South Park, where gold is found in some of the rhyolites. Mr. Marvine found a number of rhyolite outcrops in his district for 1874. They are all of small extent only, but typical.

In the Uncompahgre group this rock occurs. It occupies, usually, a position superimposed upon the trachytes. Bluffs and small hills are formed by it near the edges of the main mass of volcanics. More exposures are found on the northern side of the Gunnison River than south of it. At that locality the rhyolite overlies trachytic breccia.* Within the main mass of the Uncompahgre Mountains a very interesting occurrence of rhyolite was observed.† A very typical rhyolite was found on a tributary of Henssen's Creek, near Station 10. At the base of a deep, narrow valley heavy masses of basalt protruded through the surrounding trachorheites. Numerous caves and tunnels, the proofs of gaseous expansion, were found in the basalt. Overlying it was rhyolite. This latter rock was thinly bedded; the stratification-lines were well marked. At first sight it appeared probable that the rhyolite had been ejected subsequent to the protrusion of the basalt. This would not be in accordance with the adopted and usually verified succession of the groups. Examination, however, showed that the rhyolitic strata dipped toward the valley at an angle of 60° to 70°, and we had before us but a detached fragment of a more extensive rhyolitic flow farther west. By the basalt this fragment had been carried up to its present position, being too small to offer sufficient resistance to disruption. At various times the relative age of rhyolite and basalt have been called into question. Perhaps the most important observation leading thereto was made by Mr. Marvine.‡ He found, at Truxton Springs, Ariz., rhyolite overlying and interbedded with basalt. It is to be regretted that it was impossible for him to find the sources whence these lavas came. Probably a rhyolitic eruption may have taken place at some locality long after the activity ejecting that rock had generally ceased, or an eruption of basalt may have occurred before the main masses made their appearance. In view of the large amount of testimony which favors the greater age of rhyolite, an isolated or even several isolated cases of such a kind can have no influence upon the classificatory arrangement. Basaltic rocks speak for a new era of volcanic activity from their very lithological and chemical character, from their mode of occurrence, and from the intimate relations they bear to erupted material of the present day. In contradistinction thereto, the trachorheites comprise a series that is well defined within its own limits, characteristically separated from others, and one that brings to its close a period of the most enormous volcanic action.

Intrusive.—At two localities, mainly, were intrusions of rhyolitic material observed, in the mountains of South Park and in the Elk Mountains. At Horseshoe Mountains Dr. Peale has found§ volcanic rocks "interstratified" with sedimentary strata. The volcanics appear to be a rhyolitic trachyte. By their passage between the separated sedimentary beds they have very thoroughly metamorphosed the latter. Sandstones are changed into quartzites, and limestones partly into marble. Some of the volcanic interstrata show very excellent columnar structure there, which is due to the rate of cooling and partly to the pressure exercised by superincumbent beds. At the Silver Heels

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* Rep. U. S. Geol. Surv., 1874, p. 170.
† Rep. U. S. Geol. Surv., 1874, p. 197.
‡ Expl. and Surv. West 100th Mer., vol. iii, p. 202.
§ Rep. U. S. Geol. Surv., 1873, p. 234.

Mountains, and several adjacent localities, Dr. Peale has observed the same phenomena. Dr. Hayden* speaks of the same occurrences, and refers to them as intrusions.

One of the most striking examples is that shown at Gothic Mountain. Dr. Hayden† gives an elaborate account of it. Rhyolitic rocks intrude into the Cretaceous shales, forming prominent, steep bluffs in the ordinarily gentle slopes near the base of the peak. Several beds of this rhyolite may be traced, one above the other, following the direction of the sedimentary strata. On Rock Creek Mr. Holmes noticed a very excellent illustration of intrusion.‡ A prominent mountain is there formed by a "rhyolitic" rock. Upon investigation it was found that the Cretaceous shales at the base were in normal position while they were dipping from the hill on one of its slopes. Further examination proved "that this upturned portion had been separated from the rest and forced upward by a wedge-like mass of intrusive rock, which belonged to the central mass of the group."

From these few examples it will be seen that true cases of intrusion may be found more frequently in rhyolitic areas than in those occupied by older trachorheites. It seems that some of the rocks at the localities just quoted more closely resemble trachyte than rhyolite, but the majority appear to belong to the latter. Intrusion occurs also in connection with the smaller dikes, but in that case is usually of but limited extent.

Anarhactic.—Perhaps the most prominent form in which rhyolite occurs in Colorado is in the character of dikes. In connection, generally, with one of the main centres of eruption, the dikes occupy definite positions relative thereto. As a rule they are found near the edges of the main mass, at places that were most favorably situated for disruption. Sometimes the general arrangement of the dikes is a radial one, and, again, they may be more or less parallel. It is evident that any upheaval, such as may have accompanied at least a portion of the volcanic eruption, will mostly result in local rupture of the upheaved masses. Fissures and cracks thus formed will be injected with the liquid or plastic volcanic material, thus forming dikes. Any grouping of fissures in definite order will be productive of dike-systems. Among all the erupted rocks of Colorado none offer so much material for study of this class of ejected material as the porphyritic trachytes. A more extended discussion, therefore, upon the various features exhibited and the factors involved will be deferred until treating of these rocks.

At the head of "Oh Be Joyful" Creek Dr. Peale§ mentions a dike as setting through the sandstones. He describes the rock composing it as having a "very compact, fine-textured, dark greenish matrix, in which are a few small crystals of feldspar." Particles of free quartz also occur in it. In the vicinity of the Elk Mountains and in the Horseshoe group these dikes most frequently occur. Near Horseshoe Mountain Mr. Holmes sketched several of the intrusive volcanics,|| which Dr. Peale describes as being very highly siliceous. I class them among the rhyolites, mainly on account of their association, and agree with Dr. Peale in his assumption that the high percentage of silica may be due to the fact of their intrusion among the sandstones.

Besides these two regions, rhyolitic dikes are of rare occurrence. Rhyolite, at best, occupies but a subordinate position in Colorado, if compared with other volcanics, and the comparative paucity of its various occurrences is therefore readily understood.

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* Rep. U. S. Geol. Surv., 1873, p. 44.
† Rep. U. S. Geol. Surv., 1874, p. 55.
‡ Rep. U. S. Geol. Surv., 1874, p. 64.
§ Rep. U. S. Geol. Surv., 1874, p. 165.
|| Rep. U. S. Geol. Surv., 1873, p. 233.

PORPHYRITIC TRACHYTE.

By far greater interest than in any of the preceding groups of eruptive rocks is centred in the group of porphyritic trachytes. This term has been applied by the geologists of this survey since 1873. As the knowledge of the special character and of the general correlations accumulated, the appellation was restricted somewhat. At present we comprise under the name of porphyritic trachytes eruptions that (1) are isolated as to their topographical character and geognostic position; (2) show all the typical characteristics of trachyte, with such additional details as may specifically separate them therefrom. The separation that has been made from the beginning has been fully sustained by evidence subsequently collected. Such evidence is furnished not only within Colorado, but also in adjacent Territories. In a very able paper* Dr. A. C. Peale has set forth and discussed the leading features of this group. His personal examinations of a number of the localities involved admirably fitted him to complete the task.

MIDDLE PARK.

Mr. Marvine† mentions the occurrence of porphyritic trachyte at Park View Mountain. It occurs there in the form of dikes, analogous to other localities. It appears that the dikes are not confined to Park View alone, but spread out from it and assert their influence wherever they go A small map accompanying the report of Mr. Marvine shows a quadricircular radial arrangement of the dikes. He says: "These dikes vary from 5 to 30 feet in thickness, some being apparently over five miles in length, and extending across the country like huge, broken walls. Where several intersect or occur near one another, their combined resistance to erosion has formed a hill, every spur of which contains a dike." These latter are well defined, and are composed of very characteristic rock. A greenish, micro-crystalline paste contains numerous opaque white crystals of oligoclase. Large simple and twin crystals of orthoclase occur throughout the mass, associated with thin transparent laminæ of oligoclase. Small six sided crystals of chlorite are found in the paste.

In speaking of dikes found on Williams River, Mr. Marvine‡ has correctly interpreted the method of action and the importance of the porphyrite trachytes from a geological point of view. He says: "The intrusive masses, ... instead of breaking across the strata here, followed along their planes of bedding, and forcing apart and upward the strata between which they wedged themselves, caused them to incline." . . . . We have here, therefore, the same action that has taken place in the Spanish Peaks, La Plata and Henry Mountains, though not carried out to its fullest extent. The result has been, as observed by Mr. Marvine, the intrusion or interleaving of sedimentary beds with eruptive material. Evidently the force exerted was not sufficiently great to cause an extensive rupture, and the trachytes remained hidden from sight to a great extent. The recognition of this fact and of the ultimate result, in spite of difficult surroundings, is one that reflects great credit upon the work of our former co-laboring geologist.

MOUNT RICHARD OWEN.

Station 32, of 1874, made by Dr. Peale and Mr. Gannett, is known as

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* Bull. U. S. Geol. Surv., No. 3, vol. iii, 1877. † Rep. U. S. Geol. Surv., 1873, p. 174.
‡ Rep. U. S. Geol. Surv., 1873, p. 186.

Mount Richard Owen.* Dr. Peale examined the region and has published a diagram thereof.† From this it appears that a series of radially arranged dikes traverse Cretaceous shales, and by metamorphosing these have given rise to the formation of a mountain. He does not regard the rock composing the dikes as typically porphyritic. It is more compact and of finer texture. Taking into consideration the large number of varieties presented by the trachyte and the comparatively intimate association with other undisputable occurrences, I think that the occurrence may safely be regarded as belonging to this class.

North and southwest of this mountain are extensive groups of porphyritic trachyte. They are more massive than is usually the case, and comprise the region containing Mount Marcellina. Dikes traverse the entire country there, connecting, in part, the detached areas of porphyritic trachyte. Inasmuch as the mountains are not so completely isolated here as is usually the case, these groups present a slight deviation from the type accepted.

SPANISH PEAKS.

In 1869 Dr. Hayden first examined the Spanish Peaks. They are located at the eastern entrance of La Veta Pass across the Sangre de Cristo Mountains. Although within a short distance of this high mountain range, the isolation of the Spanish Peaks is complete. They rise from the adjoining low country to an elevation of 13,623 feet. Surrounded on all sides by sedimentary beds, they have preserved the principal feature distinguishing porphyritic trachyte eruptions—isolation. Dr. Hayden characterizes them as "a gigantic dike."‡ This expresses essentially their structure. During 1875 I visited them, and, in spite of the advanced season, was able to collect some highly interesting data.§ Structurally the two peaks differ. The eastern one may be regarded as the main point of outflow for the volcanic material. While there the main mass of the mountain is composed of porphyritic trachyte, the western peak is chiefly built up of sedimentary rocks. There is a connection between the central masses of the two, which appears in the saddle dividing them. Through a main fissure, striking, probably, about east 20° north, the trachyte ascended in a viscous or plastic condition. Whatever may have produced the upheaval of the Carboniferous beds through which the lava passed, resulted in parting many of them parallel to their stratification. Into the wedge-shaped openings thus produced the lava entered, forcing the strata to retain their distended position. Simultaneous with or immediately following the initiatory upheaval was a disruption of the rigid beds. This took place primarily in the direction of east 20° north, the strike of the most extended line of eruption. Issuing from that, and more particularly from its western termination, are a very large number of radial dikes. Some of these evidently did not reach to the surface at first, but gradual denudation has brought to light the material inclosed in the fissures. Standing on the summit of West Spanish Peak the radiating dikes can readily be traced. They form prominent, high walls, leading down from the mountain and sometimes extending into the plain below for a number of miles. Their distribution is a singularly regular one, and the constancy of each individual dike, as regards its course, is surprising. From the present

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* Report of Reconnaissance in the Ute country, p. 40.
† Rep. U. S. Geol. Surv., 1874, p. 165.
‡ Rep. U. S. Geol. Surv., reprint, 1867 to 1869, p. 153.
§ Rep. U. S. Geol. Surv., 1875, p. 128.

position of the dike-walls it is apparent that an enormous amount of sedimentary material must have been removed since the eruption took place. Furcation and crossing of the dikes is also noticeable in this locality. Wherever an additional strain was exerted on the strata they broke in some other direction, thus causing the effects now observed.

As might be expected, the passage of hot material in a viscous or plastic state has seriously affected the sedimentary rocks with which it came in contact. It has been stated above that the lava passed through Carboniferous strata. These are composed of sandstone, with thin beds of shale. In examining the contact between these rocks, it will be found that the sandstones are thoroughly baked, altered into quartzites, and, in rarer instances, into an aggregate closely resembling granite. Shales are metamorphosed into hard, brittle argillites. It may be observed that a short distance off from the dikes or intruded masses the metamorphosis becomes less pronounced, and the normal constitution of the rock again appears. So far as could be seen, no complete fusion of inclosing and inclosed rocks took place. This demonstrates that either the degree of heat which the lava showed was not a very high one, or that it lasted but a short time.

It is a very difficult matter to arrive at any conclusions regarding the degree of heat which lava contained at the time of its being injected into fissures. So much we can say in the present instance, that the material must at least have been in a plastic condition. Not only does the complete filling of fissures and interstratal openings point to such a conclusion, but more direct evidence is also not wanting. On the sides of a number of dikes we find the impression produced by the edges of strata formerly in contact therewith. In other words, the fissure or "gash" in the sedimentary rocks may be termed the mould, while the dike itself is the cast thereof. Frequently such marks are so well preserved that it can be determined whether the rock inclosing the volcanic material was, for instance, sandstone or shale.

Some of the dikes evidently flowed over upon the surface at the time of eruption, forming small, regular hills or buttes. More frequently can this be observed in connection with those filling the largest fissures.

Upon the sedimentary beds and their absolute position this eruption has had a very definite effect. It has raised the entire mass, *a priori*, has produced vertical distention by entering interstratal fissures, and has resulted in horizontal expansion. Had not the fissures been filled, many or most of them would have closed again. As the separated edges of strata were kept apart, however, by the lava, which soon assumed rigidity, the primary lateral and vertical displacement was retained.

It is apparent that so singular a mountain-structure must manifest itself in a marked manner on the exterior. Viewing Spanish Peaks from a short distance, the first striking feature noticed is the regularity and sharpness of their ridges. Added to this, we observe the symmetry of the entire structure and the striking singularity of minor details. Examination develops the fact that nearly every one of the ridges leading to the summit is surmounted by a dike. This dike, together with the hardening of the contiguous strata it has caused, has resulted in the formation of the ridge itself. Due to the regularity of the radial arrangement of the dikes, therefore, is the symmetrical distribution of the ridges. Between the ridges the sedimentary material has not been reached by the power of metamorphosing agents, hence has readily succumbed to eroding influence. As the result, we find deep gorges, growing very narrow toward the bottom, separating the individual ridges.

Among all the mountains that have come under my observation, none

has been fraught with the absorbing interest presented by the Spanish Peaks. Not only have we before us a volcanic rock of most peculiar type, but we have an opportunity, rarely afforded, to study directly the multiplicity of effects produced by volcanic action.

Petrographically, the trachytes of the Spanish Peaks belong to the great class that is so well characterized. A microcrystalline paste contains minute crystals of black mica. The color of the paste varies, but gray and greenish tints predominate. Opaque crystals of white oligoclase are dispersed throughout the entire mass. In sharp contrast to them are black or dark-green acicular crystals of hornblende. Minute grains of quartz occur sparingly, and probably have their origin in the sandstones through which the lava passed. It remains to establish the relations of all these rocks by the aid of the microscope more definitely, but I am persuaded that the correlations thus far made will be correct in the main.

HUERFANO REGION.

The Huerfano region stands in close relation to the Spanish Peaks. As belonging to one group, I regard the Sheep Mountains and Muralla Peak, south of Huerfano River.* They are composed of porphyritic trachyte. Veta Peak is the most southerly one. Drawing a line along its crest, it will strike the two hills farther north in a direction of north 21° west. Although there is no apparent connection between them above ground, they are so completely alike in every respect, that I assume a continuity of the volcanic material lower down. Muralla Peak shows a number of dikes radiating from its centre. They have given rise to the formation of sharp ridges and are prominent features in the landscape. While the trachyte of Veta Peak is one of a typical character, that of Muralla Peak verges closely upon basalt. But few segregated minerals are found in it, and those only of very small size. From the intimate association, however, and the relative position and appearance of this rock, I refer it to the same group.

Badito Peak, at the southern end of the Greenhorn Mountains, belongs to the same class. In every particular is it conformable with the typical occurrences. A number of dikes, one of them reaching a length of 13 miles, occur independently in the same region. Porphyritic trachyte composes them, and some of them bear evidence of not having reached the surface at the time of eruption.

That entire section of country along the Huerfano and Cucharas Rivers has been one of maximum disturbance during the Post-Cretaceous period. It is highly probable that the time of eruption will fall within the Tertiary period. Enormous forces must have been brought to bear in order to produce the extensive rents that we observe to-day. Undoubtedly many of the flexures of sedimentary strata in that region are due to volcanic activity, the evidences of which are not brought to the surface by denudation. It seems as if a large portion of the strata lying far below must be completely reticulated by the action of anarhactic force. That but a small portion, comparatively speaking, of the power employed could make itself felt upon the surface, may safely be assumed.

LA PLATA MOUNTAINS.

The La Plata Mountains are located in the southwestern portion of Colorado, at the headwaters of Rio Mancos and Rio La Plata. Mount Hesperus is the highest peak of the group, rising to an elevation of

*Rep. U. S. Geol. Surv., 1875, p. 133.

13,135 feet. Mr. Holmes has studied this group very carefully, and has furnished a valuable report thereon.* To the eastward of Mount Hesperus is Mount Moss. This latter is composed entirely of porphyritic trachyte, while the former is formed essentially by a succession of volcanic and sedimentary beds. Cretaceous shales, more especially, form the main bulk of sedimentary material. After careful study, Mr. Holmes prepared an ideal section,† which presents his view of the action that produced the formation of this mountain. Either the force of the rising volcanic mass, or that initiating the eruption, has forced the sedimentary strata upward, until they assumed the shape of a dome. Vertical disruption and parting of the strata has resulted therefrom. Wherever the breakage was greatest, there the largest quantity of volcanic material was ejected. It was forced vertically into the fissures formed, and laterally into the interstratal spaces. Dikes and interleaving volcanic rock show the evidence thereof. Eventually the dome burst, and, through gradual denudation, the result, as observed to-day, was achieved. Much of the sedimentary material must have been broken, and could offer but slight resistance to decomposing and eroding agents.

This very complete intrusion of trachytic rock among sedimentary beds has been productive of thorough metamorphosis. The network of volcanic sheets envelops so large a proportion of sedimentary beds, that these are altered to a high degree. Mr. Holmes cites one instance where the Cretaceous shales are in contact with the trachyte of mountains south of Mount Hesperus; he says: "The exact point of contact cannot be determined, as the metamorphism has been so complete that the shales seem to change gradually into trachyte." Instances of this kind are not rare in the La Plata Mountains. They argue forcibly for the acceptation of a very high degree of heat which the trachyte must have possessed at the time of its ejection. As elsewhere, under similar circumstances, the shales are changed into argillites; have become hard and brittle. Toward the exterior portions of the mountain-group there are numerous dikes; metamorphosis in their vicinity is thorough, but as we recede from them we gradually find the unchanged shales again.

Regarding the trachyte, which composes the entire mass, it may be stated that many varieties are found. As a type we may accept a gray to greenish microcrystalline paste, with numerous opaque, white crystals of oligoclase, minute crystals of black mica which occur sparingly, and acicular crystals of black or dark-green hornblende. At some localities the trachyte changes into a crystalline aggregate. This is owing, so far as can be determined, to the fact that the volcanic material has "absorbed" a large quantity of the rock through which it passes. Although the same feature may be noticed elsewhere, it is rarely so fully developed as here. I will have occasion to discuss this more fully below.

One of the most striking occurrences in the La Plata Mountains is the existence of metalliferous veins. They occur with in the metamorphosed area, near the central portion of the mountains. Probably the fissures containing them were formed at the same time with those now filled by dikes and by the same force. Mr. Holmes observed no regularity in their arrangement, however. He states that the veins frequently leave the metamorphic and enter the unchanged sedimentary areas, without any appreciable alteration of course or other characteristics.

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* Rep. U. S. Geol. Surv., 1875, p. 268. † Ibid., p.2 70.

SIERRA EL LATE.

The El Late Mountains are located in the extreme southern corner of Colorado. Mr. Holmes visited and examined them during 1875. His report thereon is thorough and replete with interest.* Essentially the genesis and present structure of the group is the same as that of the La Platas. Ute Peak is the highest mountain of the El Late. Mr. Holmes furnishes a very lucid explanation of the primary distribution of the porphyritic trachyte. He assumes an ejection through a narrow fissure or tube in the hard, underlying sedimentary beds. Upon reaching the softer, more easily yielding Cretaceous shales, the volcanic material found an opportunity to expand laterally. An arching of the shale strata was formed, and during the passage of the lava these were broken into innumerable fragments. Being inclosed in the hot, viscous trachyte, they were, in part assimilated thereby, in part very thoroughly metamorphosed. A notable fact is, that fragments of no other rock than of shales is found in the trachyte. This tends to show that the underlying strata were either very little broken, or, if broken, the fragments have been so thoroughly altered as to enter into the composition of the trachyte. This latter view seems probable from the fact, that Mr. Holmes observed small crystals of quartz in the rock from Hermano Peaks. At that point the rock is composed of a bluish-gray microcrystalline paste, with large crystals of white oligoclase. Crystals of sanidite occur sparingly and are very minute. Acicular crystals of a green amphibolite are dispersed throughout the entire mass.

A number of dikes are in connection with the group, some of them extending for considerable distance. Viewed as a whole, the mountain group does not appear so much as the result of one massive outpouring of volcanic material, but as a distention, on a large scale, of sedimentary beds by the intrusion of trachytic masses. The type is expressed in this mountain group as well as in the La Platas, and is one that may be regarded as a standard for eruptions of porphyritic trachyte. Distinct in all minor details from other ejections of volcanics, they present a class that cannot be mistaken if once the genesis and structure is recognized. It seems probable that eventually groups of mountains that now are not fully understood will be referred to this class.

SAN MIGUEL GROUPS.

Mount Wilson Group.—The highest of all isolated trachytic groups is that containing Mount Wilson. Rising from a base of about 8,000 feet, this peak reaches an altitude of 14,280 feet.† During the season of 1874 I visited the locality, after having seen the enormous outflows of volcanic material to the east and northeast. This group stands perfectly isolated at present, but I am inclined to assume a former connection to the eastward. So far as could be determined, a portion of the base of the mountains is formed by trachyte No. 3. Porphyritic trachyte has broken through this, however, and occupies the most central positions. We have in this instance a more complete type of eruption than is generally observed among the rocks of this class. This fact may account for the superior height of the main peak. Dikes occur in connection with the main mass, and the characteristic dome-shaped curving may be noticed. It seems, however, as if the force projecting the volcanic material upward had been one so severe that ruptures immediately took place sufficiently large to allow the passage of enormous amounts of the lava.

* Rep. U. S. Geol. Surv., 1875, p. 272. † Rep. S. U. Geol. Surv., 1874, p. 207.

Dolores Peak and Lone Cone.—Mr. Holmes furnishes a section extending from Mount Wilson to Dolores Peak and thence to Lone Cone.* From this it would appear that both are essentially but a continuation of the Mount Wilson upheaval. The trachytic mass has penetrated the older mesozoic beds, has broken through the massive Dakota sandstones, and finds an opportunity for lateral expansion in the Middle Cretaceous shales. Dikes and intrusive sheets of volcanic material are not wanting. The latter appear either as interbedded or in the form of wedges.

Viewed as a whole, the three eruptions undoubtedly belong together. They occur in approximately a straight line, and their general as well as detail character is perfectly conformable. It is a significant fact that mainly the Middle Cretaceous shales are made the recipients of lateral intrusion. Evidently the lower sandstones did not offer the same facilities. Whether this may be the result of pressure produced by the superincumbent strata, or whether the uplifting force was not sufficient to produce a parting of the beds, is a question for investigation. It seems a very difficult matter to measure the relative power of the force employed, but phenomena of this character may eventually furnish some tangible clue.

Bear River Mountains.—A portion of the Bear River Mountains may be said to belong to the porphyritic trachyte group. During 1874 I visited the eastern part and found rocks that must be referred thereto.† A mountain, upon which Station 36 was made, rises to an altitude of 12,554 feet, and may be considered as the main point of outflow. From there the trachyte has spread over Carboniferous sandstones to the westward, over Middle Cretacious shales to the east. Instances of intrusion were observed at several points. One was noticed in particular where the trachyte appeared as directly interstratified with red Carboniferous sandstones.‡ Near the top the intrusive sheets are wedge-shaped, but lower down they closely resemble interstrata. I am inclined to the opinion that we there have one of those instances that shows only a small portion of the volcanic rock on the surface, while the main mass remains buried. Considerable disturbances from the normal position have been produced by this series of intrusions, although no striking forms have resulted therefrom. So far as seen, there was but little disturbance of the Cretaceous shales, owing, perhaps, to the fact that they are a short distance removed from the centre of ejection. Much denudation and erosion has taken place at that locality, and at some points has brought to light portions of formerly hidden volcanics.

At Station 36 the rock is very characteristic. A grayish-green micro-crystalline paste contains innumerable crystals of opaque, white oligoclase, giving the trachyte the appearance of a very uniform pudding-stone. Small acicular crystals of green and black hornblende are dispersed throughout the paste. A short distance from the station the rock represents a type that is frequently found in connection with porphyritic trachyte. An almost white micro-crystalline, feldspathic paste contains minute crystals of transparent oligoclase, and very small crystals of a brown mica. It is highly probable that, were we able to go to any considerable depth, we would find the oligoclase to be transparent throughout. The opacity, which it shows near the surface is most likely due to a partial alteration into caolinite. Oligoclase readily changes upon exposure, particularly in regions of varying temperature.

* Rep. U. S. Geol. Surv., 1875, p. 244.
† Rep. U. S. Geol. Surv., 1874, p. 207.
‡ Rep. U. S. Geol. Surv., 1874, p. 219.

SIERRA LA SAL.

The Sierra La Sal, or Salt Mountains, is properly composed of three groups, with, as Dr. Peale says*, "sedimentary saddles separating three eruptive centres." During 1875 he visited that region and examined carefully the structure of the mountains.† Rising to a relative elevation of 8,000 to 8,500 feet above the adjoining river-valleys, these mountains are located just west of the western boundary of Colorado, at about north latitude 38° 30′.

The entire structure of the mountains is a simple one, being mainly a vertical eruption along a line trending approximately north and south. Newberry in 1859 already noticed the probable eruptive character of the group and compared it to that of the Sierra Abajo.‡ From Dr. Peale's sections, it appears that the La Sal Mountains owe their formation to the same process that caused the elevation of the La Platas and other closely-related groups. Instead of having but one fissure for the ejection of the main mass of volcanic material, we find two, running parallel, in the middle and northern groups. This is accompanied by a variation from the simple, dome-shaped flexure of the sedimentary strata. Most strikingly is this demonstrated in the middle group. There we find two mountains, both of them of nearly 13,000 feet altitude. While the Lower Cretaceous strata dip away both to eastward and westward of the entire group, they have been raised to a considerable elevation between these two mountains. At present they form a saddle between them, and are curved in the form of a synclinal fold. Evidently the force exerted in either mass of volcanics was not sufficiently great to carry it high enough to obliterate this remnant of sedimentary strata. Triassic and Jurassic beds have been severely affected by the trachytes and their eruption. Metamorphosed fragments testify to the heat, while broken and disrupted strata indicate the enormous force employed.

Interleaving of volcanic material with sedimentary beds may be observed near the junctions of the main fissures with the edges of strata torn apart. Apparently the Palæozoic groups take part in the general flexure of strata, indicating the deep-seated source whence the trachytes were derived.

The rocks, so far as observed, agree closely with those from other localities belonging to the same class. Unfortunately the specimens were lost, but sufficiently detailed examinations had been made in the field to establish their character.

SIERRA ABAJO.

The Sierra Abajo was visited by Mr. Holmes during 1876, and his report thereon is published in this volume, pp. 189, 193. Dr. Peale gives a short synopsis of its character,§ which shows it to be perfectly conformable in its features with the other groups composed of porphyritic trachyte. The range, if it may be so called, is situated due west of the San Miguel Mountains, at about north latitude 37° 50′, west longitude 109° 30′. A number of prominent points compose the group. Evidently, as in other regions of similar construction, the lava has been ejected through one or more fissures, and, upon reaching the yielding Cretaceous shales, has spread laterally. Thus intrusive masses are formed, similar to those

*Bull. U. S. Geol. Surv., 1877, No. 3, vol. iii, p. 558.
† Rep. U. S. Geol. Surv., 1875, p. 59.
‡ Expl. Exp., by J. N. Macomb, 1859, 1876, p. 93.
§ Bull. U. S. Geol. Surv., vol. iii, No. 3, p. 558.

observed elsewhere. Dikes have been formed, traversing the sedimentary strata, and composed of the same material that is shown in the main mass. Newberry, in 1859, recognized the local eruptive character of the group.* Although the Sierra Abajo is not within the limits of Colorado, its relations with Colorado groups are so striking that a brief mention has here been made.

SIERRA CARRISO.

This, like the preceding, is not situated in Colorado, but in the extreme northeastern corner of Arizona. It is similar, in every respect, to the El Late Mountains. Mr. Holmes visited it during 1875, and published an interesting account.† The highest points of this group rise to an altitude of 9,000 feet, the most elevated of which has been named Mount Pastora. Here, as in the other groups, porphyritic trachyte has found its way through the superincumbent sedimentary strata, and has spread out laterally, upon reaching such strata as would permit its expansion. It is highly probable that but a limited quantity of the lava originally reached the surface, but that subsequent erosion removed the Cretaceous beds, thus exposing the trachytes. Mr. Holmes has observed a very curious occurrence in connection with the Carriso group. He finds that the Cretaceous sandstones show a flexure which indicates the primary formation of either an arch or a dome. Covering these strata are layers or flows of trachyte that "are also flexed with the sandstones, and appear as if they might at one time have formed part of the arch." Two explanations present themselves for this phenomenon:

(1.) The eruption of volcanic material may have been spasmodic. Long periods of time may have elapsed between the successive ejections of lava.

(2.) The overlying trachytes may form an, originally, intrusive sheet. In this case the higher beds of sedimentary strata have been removed by erosion.

I am inclined to this latter view, from the fact that at most localities the eruption of porphyritic trachyte appears to have progressed without any appreciable intermission, and because there is ample evidence of extensive erosion.

Huge fragments of the sedimentary material have been carried upward, together with the lava, and now present the characteristic metamorphoses observed at so many points. Portions thereof have undoubtedly entered the trachyte, thus changing, to a certain degree, its composition.

With the Sierra Carriso ends the discussion of such groups as have been referred directly to the porphyritic trachytes. It remains to summarize the results, and treat, more connectedly, of the various unique features belonging to these groups.

RÉSUMÉ OF PORPHYRITIC TRACHYTE.

I.—LOCATION.

From the preceding pages it will be observed that the most noticeable feature of the location of groups referable to porphyritic trachyte is that of *isolation*. None of them are in direct connection with any mountain range or groups. They stand in no intimate superficial relation with other eruptions, whatever might be their associations near their sources. Without exception, almost, they are surrounded by sedimentary beds.

* Rep. Expl. Exp. J. N. Macomb, 1859, 1876, p. 100.
† Rep. U. S. Geol. Surv., 1875, p. 274.

It may be noticed that, in a general way, the various groups have a combined strike parallel to the main strike of the great volcanic mass of the Uncompahgre and San Juan Mountains. The trend of those groups not far distant from the main volcanic area may be regarded as being at angles approximating 90° thereto. In contradistinction, those that are located far off have a trend nearly north and south. This arrangement, though the connection may not appear perfectly clear, seems constant, and must therefore have some bearing upon the correlations of the two classes of eruptives.

II.—PHYSICAL APPEARANCE.

Dependent, in a measure, upon their location is the exterior appearance presented by these groups. They rise to considerable absolute altitudes from the comparatively low country surrounding them. Mount Wilson reaches the highest elevation among them, and is followed by the Spanish Peaks. In conformity with their structure, the mountains composed of porphyritic trachyte show unique exterior feature. Taking a general view, they may be described as isolated groups rising abruptly from the level of the surrounding country. Sharp summits characterize the peaks. Erosion has been productive of severe corrugation. Ridges and spurs leading up to the highest points are sharply defined, very often falling off precipitously on either side. Steep slopes are noticeable, especially near the tops of the high peaks. A linear arrangement of the most prominent points may be observed, due to the strike of the points or fissures of outflow. Within a certain distance from the groups, and within their limits, the dikes have produced characteristic forms. Walls, or isolated masses of rock, and steep, hogback-shaped hills denote their presence.

Usually the colors exhibited by the rocks are dark. Bright shades of red and green are not wanting, however, owing to the presence of ferric oxygen-compounds.

The entire habitat of the porphyritic trachyte groups is so striking that, if once seen, it will rarely be forgotten. All the special features mentioned above combine to produce an effect that is unlike any other observable in the same region.

III.—STRUCTURE.

Two types of structure may be distinguished:

(1.) Mountains, or groups of mountains, are formed by the agency of a definite arrangement of numerous dikes.

(2.) Large masses of volcanic material have been ejected through one or more apertures, have been accompanied by a stratigraphical disturbance, producing arched or dome-shaped flexures of sedimentary beds, and have formed, aided by erosion, mountains and mountain-groups.

To the first series belong such occurrences as have been observed at West Spanish Peak, Park View Mountain, and Mount Richard Owen. A radial arrangement of fissures was subsequently filled by hot volcanic material. While breaking up, in part, the sedimentary beds through which the lava passed, it has, at other points, enabled it more successfully to withstand erosive influences.

Although it cannot be, and is not, claimed that solely erosion has produced the present relative elevation of such mountains, it has been a very important factor in their genesis. Furcation, crossing or reticulation of the dikes has resulted in the formation of points or series of

points especially capable of resisting disintegration. Sharp points on ridges or even isolated hills in the adjoining valleys indicate their position.

This system of mountain structure is one that has not heretofore been observed, so far as I am aware. Until it was pointed out in the porphyritic trachyte groups it had not appeared elsewhere. Perhaps the best locality, one where it may be studied together with its most successful results, is that of the Spanish Peaks.

On a more extensive scale than the preceding series is the second one. Although here, too, the dikes enter very largely into consideration, they are of but secondary importance. Regarding the structure schematically, we may state that in this instance the volcanic material is contained mainly at or near the surface.

Having passed upward through fissures or tubes formed in comparatively hard strata, the lava finds such that will yield to lateral compression and to vertical separation caused thereby. This permits a horizontal expansion of the lava. As compared with the preceding group, this form may be considered the more complete. In the one case all the volcanic material is still confined within the limits of the original apertures of emission, while in the other secondary openings are formed permitting the entrance of foreign matter.

In many instances it may remain a question in doubt whether any but a very small portion of the lava originally reached the surface. Primarily it would appear as if this question might readily be decided by the shape of the mountain or mountain-group. Upon examination, however, this involves many considerations. Wherever *flows* have extended from the central regions of outflows, covering such strata as were exposed at the time of eruption, there is no difficulty in making a determination. Denudation may produce an effect easily mistaken for surface-flows. Erosion and disintegration subsequent to exposure will produce results that may defy the recognition of the original condition of the portions involved. From this it may be seen that very few applicable data can be obtained whereupon to base any opinion pertinent to the question. While we have evidence that the sedimentary beds have been arched to a very considerable elevation (Sierra La Sal) and have sustained but few ruptures, it seems, *a priori*, improbable that such should be the case in all instances. Gradual denudation can remove enormous quantities of material. It is not to be supposed, however, that it would remove a sufficient thickness of strata to permit the assumption that most of the groups were formerly covered by sedimentary deposits. The flexure of strata in the cases of the eruptions under consideration is established. It seems probable, therefore, from the very magnitude of the arches, that they broke at the points or along the lines of weakest resistance, thus permitting an emission of large quantities of the lava. As a rule, I think we may state that the central portions of the groups reached the surface, but that much of the lateral material now exposed was formerly hidden under a mass of sedimentary rocks. This will apply equally to nearly all of the groups observed.

IV.—RELATIONS TO SEDIMENTARY FORMATIONS.

Groups of mountains composed of porphyritic trachyte are found mainly in regions exhibiting Cretaceous beds. Among such we count all the more westerly ones. A partial exception is made by West Spanish Peak. There the trachyte has mainly broken through, and is contained in fissures formed in Carboniferous strata. At a few localities it

was observed that the Palæozoic beds were disturbed. Triassic and Jurassic strata are more frequently affected. Lower Cretaceous sandstones are broken through, and are at many places altered into quartzites. The largest amount of disturbance the Middle Cretaceous shales have suffered. They have been distorted; their normal position has been infringed upon by the trachytic lavas until both horizontal and vertical displacements have occurred. Within the limits of the Middle Cretaceous shales we find the greatest development of the trachytic masses. Offering less resistance than underlying beds, partly from their position, partly from their texture, they have been penetrated largely by the lava. Mainly in an approximately horizontal direction has this penetration taken place. To-day we find its evidence in the huge sheets and wedges of porphyritic trachyte that interleave the shales.

At several localities Post-Cretaceous strata are traversed by dikes belonging to this group. They are not separable therefrom, either in the character of their occurrence nor in their petrographic constitution.

V.—INFLUENCE UPON SEDIMENTARY STRATA.

The influence of the porphyritic trachytes upon sedimentary rocks is dependent upon the primary effect produced thereupon. The question referring to the great displacements of strata does not enter into consideration at this place. We here consider only that produced by the contact with each other. This may be:

(1) Preserving, or
(2) Destroying.

From numerous observations it has been learned that the effect of the hot lavas upon sedimentary rocks has been such as to *metamorphose* them. This is accomplished in a very direct, uniform manner, but its results differ somewhat. We find that by the action of heat sandstones have been changed into hard quartzites, and even into aggregates closely resembling granites. We find argillaceous, partly dolomitic shales transformed into rocks that the experts would term micaceous schists. Shales and marls are altered into argillites and porcelain jasper. In case the cohesion of the entire mass is not destroyed, this process has been a preserving one. Instances do occur, however, where the unity of the mass has been broken up, where the result of heat upon the strata was such as to render them more effectually attacked by eroding agents. This, in one sense, may be characterized as destruction of the strata.

I have in view, however, still another process by which the destruction of originally unchanged sedimentary rocks is accomplished. This is due to the action of fusion. The products thereof I name

SYMMORPHIC* ROCKS.

In passing through the fissures in sedimentary strata, the lavas of this trachytic group have frequently enveloped fragments thereof of more or less weight, and have carried them along. Such fragments can often be found in a metamorphosed condition. Taking the case that they were small, though numerous perhaps, it is easy to see that they might be entirely assimilated by the hot lava inclosing them. This would

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*NOTE.—I have coined this word to express what is described in the subjoined page. It seems essential, and is certainly more convenient for descriptive purposes, to separate so interesting a group by a definite, expressive term.—E.

produce a change in the chemical composition of the rocks. Upon examination it will be found that such a change can be observed in many of the dikes. It stands in direct proportion, so far as known, with the chemical composition of the strata traversed. Dr. Peale and Mr. Holmes have collected specimens from the Western groups of porphyritic trachytes that defy identification by a lithologist. It was found in such instances, upon partial examination only, that the rock contained considerable quantities of the main constituents shown by such strata as it had passed through. Thus, for instance, one specimen from a dike contained carbonate of lime. Investigations being made, it was found to penetrate a series of calcareous shales. It is evident that the calcium could not at first have been assimilated as a carbonate. It was taken up as a carbonate, turned by heat into calcium oxide, and remained as such until percolating waters and exposure to atmosphere enabled it to acquire a sufficient amount of carbonic-acid gas again to form carbonate of lime. Many similar instances have been observed, showing how widely spread this assimilation is. It remains to be stated that no ultimate chemical examinations have been made of these cases as yet, or more definite results would be presented.

Clearly the opportunity for assimilating such foreign material is greatest in a narrow fissure. In proportion the volcanic lava has exposed to its action a far greater surface of unchanged rock. Its narrow width will more readily permit a thorough permeation of the entire mass, and its peculiar methods of cooling may be productive of more striking results. In dikes, therefore, rather than in the large masses of volcanics, must we look for the variations produced by the foreign matter entering into the composition of the erupted material.

As the result of additional quantities of silica, alumnia, lime, magnesia, and other constituents, from the source above described, totally changes the original character of the lava, I comprise the series under the name of "symmorphic" rocks.

VI.—CORRELATION WITH OTHER ERUPTIVES.

Viewed in their character as eruptives, the porphyritic trachytes may be compared to the granites of the Elk Mountain region. Both are isolated, both have broken through sedimentary strata—probably at or after the close of the Cretaceous period. Both classes of occurrences are accompanied by disturbances of the sedimentary beds. Dr. Peale* has described them both in the same paper, and points out their analogies and dissimilarities. He has seen the most typical points of either class, and is competent to judge.

So far as I can determine, there is no direct correlation between the eruptions of the group under consideration and the great, massive eruptions of the Uncompahgre, San Juan, or other regions. I consider it highly probable that there is a chronological and dynamical connection, but none that appears as such at the present time. From all that can be learned the eruptions of porphyritic trachytes occurred very near the time that we must assume for those of rhyolite, prior to basalt. I am unable to state which of the two, rhyolite or porphyritic trachyte, should be regarded as the older. In mineralogical constitution the rocks of the latter group have a general resemblance to trachyte proper; less so to rhyolite. The lower percentage of silica, and its usual absence as such, constitute a considerable portion of the similarity.

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* Bull. U. S. Geol. Surv., vol. iii, No. 3, 1877.

Free silica has not very often been observed in the porphyritic trachytes, and, whenever found, the suspicion lay near at hand that it might have been received during the passage of the lava through some highly siliceous stratum. In consequence of their greater direct affinities to trachyte, I have placed them so as to precede, in age, the rhyolite in the first table, but have reversed this succession in the discussion, in order to give expression to my doubts. Nowhere were rocks of this group found in sufficiently intimate contact with the younger trachorheites to admit of any definite interpretations of their relations. One feature may be regarded as distinctive, however. While the trachorheites are usually found to have their origin in regions occupied by metamorphic rocks, the porphyritic trachytes are found in sedimentary areas. This argues an inference that enters into consideration in the study of their original sources.

VII.—AGE.

A certain amount of definite information has been collected with reference to the age of the porphyritic trachytes. It has been mentioned above that they are found mainly in Cretaceous areas. At Park View Mountain and south of Spanish Peaks dikes formed of it cut through Post-Cretaceous strata (lignitic series). I am not aware that any strata younger than these have been traversed by them. As these occurrences are thoroughly characteristic at both localities, and as their connection with the entire group has been satisfactorily established, we may regard the period of eruption as falling very near the beginning of the Tertiary epoch. I am inclined to regard it as rather belonging to an era *after* the beginning of Tertiary sedimentation. As each of these formations required enormously long periods of time for its deposition, we are not enabled to make an assertion that would confine the eruptions within narrow chronological limits. Large masses of Tertiary beds may have elsewhere been deposited while the region exhibiting volcanic activity had not yet been invaded by water or sediment.

BASIC VOLCANIC ERUPTIVES.

DOLERITE.

Among all the volcanic rocks in Colorado dolerite occupies the least prominent position. Most likely many of the rocks that are classed with the basalts should properly be referred to dolerites. It is a matter of some difficulty to separate the two in the field, however, owing to their mode of occurrence and to the similarity of lithological constitution. Perhaps the best criterion for separation of the two may be the presence of olivine in the basalts, and this has been made the basis for discrimination in the subjoined pages. Although, at first glance, the occurrence of olivine might seem to afford a positive element of recognition, the decomposition and eventual disappearance of this mineral greatly increases the difficulty. Were it possible to employ microscopic tests in every instance, but little doubt could remain as to the true character of the rock. It is evident, however, that this means can be employed in isolated cases only, and we are forced to base opinions upon less reliable bases.

Dolerite occurs in the Uncompahgre group in small quantities, associated with basalt. The connection of the two is so intimate, and the former occurring in so subordinate a position, that they could not

well be separated. By far the largest masses found were observed by Mr. Marvine in doleritic breccia.* In the region of the Hot Springs, Middle Park, Marvine observed heavy beds of doleritic breccia underlying strata belonging to the Post-Cretaceous lignitic series. Their maximum thickness is 800 to 900 feet. So far as could be determined, this conglomerate must have been derived from former extensive deposits of dolerite and, in part, basalt. The rocks are characteristic, are water-worn, and deposited analogous to true sedimentary beds. Their relative position changes somewhat at different localities, but usually they occupy a definite horizon. Most likely the material was ejected prior to the eruption of the main mass of basalts, and an extensive action of erosion has early produced the effects we now observe. This is the chief occurrence of dolerite in Colorado, though I do not doubt that upon careful investigation certain groups heretofore referred to basalt will be resolved into dolerite and diabase.

BASALT.

Basalt occurs at many localities throughout the State. It is found in varying quantities and of different methods of occurrence. Similar to trachyte, it takes a prominent part in shaping the exterior features of the country. Analogous, also, to trachyte, we find its associations to be constant within certain limits.

Three types of eruption may be distinguished:

Massive,
Anarhactic, and
Isolated.

To the first we must count those basaltic areas that are in intimate connection with the trachorheitic group, and those where enormous masses of the lava have been poured out over sedimentary beds.

The second group comprises occurrences that we observe most frequently in the younger sedimentary formations. Fissures, mainly formed in the strata, have been filled by basalt, and now are found as dikes.

Isolated groups occur most frequently in the lower country, both south and east of the main mountain-masses. They are thoroughly characteristic in their features, as well as in the relations to surrounding rocks.

I.—MASSIVE.

San Luis Valley.—In the southwestern portion of San Luis Valley, and extending from there westward, we find a very large area covered by basaltic rocks. This area commences on the eastern slope of the San Juan Mountains, reaching far down into the valley. Prominent in the southern portion are two high peaks, Mount San Antonio and Ute Peak. We find, by examining the western edge of the basalt area, that these rocks rest directly and conformably upon the trachorheites composing the mountains. From there the basaltic beds slope eastward, dipping toward the valley. At all points the successive flows of lava can be readily traced. They are perfectly distinct, and greatly aid in the recognition of the structure of the entire region. During 1875 I visited the region,† and made an attempt at determining the points of outflow for the entire area. So far as any definite opinion can be held, I incline to the view that Mount San Antonio and Ute Peak indicate the former points of outflow. A study of these (topographically) isolated mountains, and the rocks com-

* Rep. U. S. Geol. Surv., 1873, p. 156, &c.

† Rep. U. S. Geol. Surv., 1875, p. 143.

posing them, leads to this conclusion. Neither of them can be compared to a volcano, although, at first glance, their position might suggest such an idea. They are essentially an accumulation of volcanic material at the points of the original vents. Undoubtedly long periods of time elapsed between the various flows of basaltic lava. Many of the eruptions producing them may not have brought forth a quantity of lava sufficient to cover much ground. In this case it would have become rigid near the point or line of ejection, thus gradually building up a mountain.

While the basalts of the entire area show remarkable uniformity of constitution, those from Mount San Antonio, for instance, present many variations. This argues in favor of the view which regards the mountain as one of the points of original outflow.

For the sake of comparison, a number of descriptions are here reproduced from the annual report of 1875. Those specimens described from the various stations represent the character of the basalt of the entire area. It will be seen how many varieties were observed on San Antonio, more, perhaps, than could be collected over the whole extent of the basalt, excluding points of outflow.

1. Station 91. Basalt.

Paste, microcrystalline; color, middle to dark gray; weathers dark-brown. Contains small spherical cavities, which appear glazed. Brown decomposed inclosures of olivine have a splendent lustre. Magnetite is segregated in small, octahedral crystals. Is altogether very homogeneous, heavy, and hard.

2. Station 96. Basalt.

a. Paste, microcrystalline; color, dark-gray, weathering brown. Olivine in exceedingly minute particles. Spherical vesicles, containing small crystals of zeolites; magnetite not visible.

b. Paste, crystalline; color, reddish-brown, weathering lighter. Crystals of black biotite occur sparingly. Olivine, decomposed, dark, splendent brown. Irregular vesicles distributed throughout the entire mass, some of them containing zeolites. Decomposition of magnetite produces the brown color.

3. Mount San Antonio. Basalt.

a. Paste, cryptocrystalline; color, dark-gray to black. Slightly vesicular; vesicles either spheroid or drawn out; in some of them deposits of zeolites. Olivine the only segregated mineral distinguishable.

b. Essentially the same as above, but highly vesicular. Vesicles frequently round, while on the same bowlder in another zone they are drawn out. No mineral distinguishable but olivine, which is partly decomposed.

c. Paste microcrystalline. Color pitch-black, with fatty lustre. Very compact. Vesicles too minute to be visible. No segregated minerals. Resembles the typical melaphyrs of Europe. Large percentage of magnetite. This variety is subject to, mainly, three modifications.

d. Physical character as above, excepting the presence of vesicles; these are very flat, drawn out to the length of half an inch. Between the larger ones are very minute ones. The rocks break into shaly fragments, owing to the fact that the vesicles have been compressed in one direction. This latter feature is still more modified in—

e. Where the compression goes so far as to produce a decided lamination. On the surface of fracture, which latter occurs only in the direction of the longitudinal axes of the vesicles, it has an appearance similar to that of the surface of a palm-leaf. The vesicles no longer

remain as such, and are only indicated by the *quasi* cleavage-planes of the rock.

f. Shows no segregated minerals whatever, and is as porous as a sponge. The vesicles are small, averaging 1 millimetre in diameter.

g. Paste micro-crystalline; its structure much obscured by decomposition. Compact; no vesicles. Color mottled red-brown and black. Small particles of olivine are distinguishable, although decomposed. This is essentially the variety *c*, without vesicles and a changed color, the result of higher oxidation of the magnetite.

h. Same as *g* in paste. Color reddish-drab. Minute irregular cavities, produced by decomposition of certain mineral constituents. Olivine inclosures reaching a diameter of 2 millimetres. This is a still further progressed product of decomposition.

i. Very much like *f.* Color grayish-brown, thoroughly vesicular. Not only are the small vesicles found as in *f*, but large ones occur, showing a glazed surface. All of them have been more or less drawn out. In its texture it closely resembles pumice.

Station 104. Basalt.

a. Paste micro-crystalline; color black. Minute crystals of feldspar and finely distributed olivine give the rock a glassy lustre. Innumerable small vesicles. Some larger ones are scattered throughout. The latter are filled with either crystalline or amorphous carbonate of lime.

Station 99. Basalt.

a. Paste grayish-black when fresh, reddish-brown when decomposed; crystalline. Black biotite in minute crystals. Olivine brown. Minute vesicles and scattering larger ones, both irregular.

It appears that after the outpouring of this basaltic lava there was an elevation of the region directly west involving a portion of the basalt. Judging from the eastern limits of the area, it seems probable that the rise westward did not exert its influence for any long distance into San Luis Valley.

As one of the characteristics of this region we may regard the "fresh" appearance of the basaltic rocks exhibited at many places. Very little decomposition and disintegration have taken place, thus preserving, in a great measure, the surface intact. This naturally results in a lack of vegetation, which, in turn, augments the appearance of freshness. In this connection reference may be made to an important fact, which is not unfrequently overlooked. Owing to the fact that decomposition has but slightly affected the rocks, only a scant growth of vegetation can subsist. From this circumstance the inference is usually drawn that the lava assumed rigidity but a comparatively short time ago. On the other hand, a rich growth of plants is regarded as an argument for greater age. It remains to be remembered, however, that if once growing vegetation can gain a hold in the soil, disintegration and decomposition of the rock will progress at a far more rapid ratio than before. It is the formation and retention of the first soil that requires a long period of time, hence exposures that look very "fresh" are not necessarily of relatively recent date.

Besides the two mountains above mentioned, there are several other prominent points that I regard as owing their existence to the fact of being points of eruption. No definite arrangement can be made out in their horizontal distribution. It may be said, however, that they occur at such points or along such lines, where the underlying trachorheites probably offered the least resistance to vertically-acting forces.

As the main characteristic of this very large area, we may regard the surprising uniformity shown by the basalt, except at the points of ejec-

tion. Evidently large masses of the lava were poured out at once, to be followed by similar eruptions at later periods. Those ejections that have built up the mountains were very limited in quantity as compared to the others, and owe to this fact, probably, their inability to cover any considerable area. The entire region is one of great interest, showing, as it does, the relations between previous and basaltic volcanic periods, besides illustrating the magnitude of the scale upon which such eruptions took place.

Uncompahgre Mountains.—Basalt occurs in the Uncompahgre Mountains at considerable elevations. It was found on several high plateaus. Upon one of them several stations were located,* and from there former connections could be traced that indicate a rather extensive basaltic area. The basalt is poured out over the older trachorheites, and occupies a perfectly conformable position. An absolute elevation of over 12,000 feet can be observed on the summit of such plateaus. Another one is found near the junction of Lost Trail Creek and the Rio Grande. Several of the high peaks show caps of basalt. From the detached fragments that we now observe, and their relative position, we can infer that at one time the larger portion of all of them were at one time connected. So far as observed the lithological character of the basalts there is perfectly uniform, which argues for former connection.

In speaking of rhyolite a locality was mentioned not far from Uncompahgre Peaks where basalt was found under the former. This I regard as one of the points of eruption, if not the only one. It is the only place where basalt is found at a low elevation. As a rule the thickness for the basalt of this region may be stated as 600 to 800 feet.

Grand Mesa.—Northwest of the localities just described we find another extensive basaltic area.† South of the junction of the Gunnison and the Grand a high prominent mesa is formed by Tertiary beds. A layer of basalt caps it throughout its entire extent, affording protection to the easily-eroded underlying strata. Dr. Peale has described this region. He gives the thickness of the basalt as about 250 feet, but expresses the opinion that this does not represent its original vertical extent. It is probable that erosion has removed a large portion of the basalts, and that we now have before us but the remnants of areas that at one time must have been very extensive.

On Eagle River and a portion of its drainage basaltic areas occur that at one time were probably connected. In South Park, and associated with the trachorheites of the Front Range, we find basalt exposures that must be referred to massive eruptions.

So far as observed, all of these bear the same relations to either sedimentary or older volcanic rocks. With these latter they are generally conformable when found in contact. Although so distinctly offset in almost every respect from other eruptives, the basaltoid group undoubtedly has been governed by the same laws that have determined the points or lines of eruption for other volcanics. They occur in the same manner, though evidently of later date, they show the same methods of protrusion, and they are analogous, in the results produced, to the less prominent members of preceding groups. From their scheme of horizontal and vertical distribution, it may be inferred that the basaltic lava reached the surface in a very high state of viscidity. This cannot always be said of the older volcanics. Taking advantage of the configuration of the country at the time of ejection, the basalt has found its way in the largest quantities to the points most readily accessible.

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* Rep. U. S. Geol. Surv., 1874, p. 202.

† Rep. U. S. Geol. Surv., 1874, p. 174.

II.—ANARHACTIC.

Two regions, mainly, may be distinguished where anarhactic eruptions of basalt occur. Of these the first is in Northern Colorado, north of White River. Numerous dikes of basalt there traverse Cretaceous and Tertiary strata. They frequently extend in straight lines for a number of miles. Analogous to the occurrences of porphyritic trachyte, the formerly inclosed basaltic rock has been exposed by the abrasion of the surrounding sedimentary beds. Vertical black walls now stand out prominently, imparting to the landscape a unique character that has found its appreciation in some of the local names given. Essentially these dikes are parallel among themselves, often separated by considerable intervening spaces.

On the northern tributaries of the San Juan River a large number of basaltic dikes occur in the Tertiary beds of that region. Along the San Juan itself such dikes may be found. Frequently they extend for many miles, exhibiting the same characteristics above given.

A marked feature in connection of these dikes is the fact that no disturbance of the strata seems to have accompanied the ejection of the volcanic material. No distortion or extensive displacement of the beds will be noticed. Evidently the fissures were formed by the action of some force that confined itself to this manifestation. Through the openings produced the lava protruded, without causing any appreciable further disturbances. Rising into the fissures, and sometimes overflowing, the lava obeyed the laws governing its eruption without any accompanying demonstration of additional force.

This characteristic brings the anarhactic into close relation with the massive eruptions. The two stand as the representatives of definite types, while the ejections of porphyritic trachyte were preceded and accompanied by more violent demonstrations. It is true that a certain amount of disturbance must have been coincident with the opening of the fissures; but it is equally true that, whatever the acting force was, it did not exert any considerable influence upon the rocks adjoining. It is evident that this feature is one of great importance in discussing the origin of eruptives and their mode of ejection. It is necessary, therefore, to note the conditions pertaining to the surroundings of erupted masses, as well as those relating directly to the latter.

III.—ISOLATED.

A number of isolated basaltic eruptions occur in Colorado. Prominent among them is that of Golden City.* Table Mountains there are composed of lignitic beds and covered by basalt. Mr. Marvine says (*loc. cit.*) with regard thereto: "The source of this lava is from beneath North Table Mountain, on the summit of which, and near the northwest corner, the remnants of a group of small volcanic cones may still be seen; weather-beaten and nearly worn away, they still suffice to show from whence the lava came." This explains, in a few words, both the source of the basalt and the character of such eruption. Not far from Golden, at Valmont, a heavy dike of the same material may be oserved. Inasmuch as we may safely regard isolated eruption as the results of local dikes that have overflowed, that of Valmont deserves mention here.

* Rep. U. S. Geol. Surv., reprint, 1867 to 1869, p. 133, and Rep. 1873, p. 129.

Near Cañon City* two small basaltic hills occur. Farther south, toward Pueblo, another may be noticed. Along the Huerfano River† a number of them may be noticed, occurring together with some dikes composed of the same material. It is a noticeablefact that all of these last-mentioned eruptions have broken through and are exposed in Cretaceous or lignitic beds. Some form low, prominent hills, others merely act as protecting covers to the penetrated strata. An interesting case of this kind is the bluff upon which a station was located near Badito. Rising rather abruptly from the surrounding country, the bluff reaches an elevation of 6,952 feet above sea-level. Three prominent cones of basalt, standing in a line on the summit of the bluff, denote the original points of outflow. Sharply defined, they are distinguishable from a long distance, and before being visited their appearance awakened the hope of seeing small, well-defined craters. Although the basaltic eruptions have been productive of forms resembling crater-cones more closely than any of the other eruptives, not one occurrence has been observed in Colorado that could directly be compared to the cone and crater of an active or typical volcano. This fact has been recognized some time since, and no exception to this rule has been discovered as yet. Instances do occur which a lively imagination could transform into a crater-cone, but upon examination they prove not to be such.

* Rep. U. S. Geol. Surv., 1873, p. 331.

† Rep. U. S. Geol. Surv., 1875, p. 131.

CHAPTER IV.

AGE, COMPARISON, AND ORIGIN OF ERUPTIVES.

AGE OF THE ERUPTIVES OF COLORADO.

Taking a general view of the subject, it is a comparatively easy matter to arrive at conclusions regarding the age of eruptives in Colorado. The more narrowly we attempt to draw the lines, however, the less material for accurate definition do we find. Though it is not difficult to assign to eruptives a period embracing the same amount of time that is allotted to some particular formation, it is less easy to state within precisely what portion of the period the greatest eruptive activity fell.

Arranging the plutonic eruptives chronologically, we have—

Diorite, oldest.
Euphotide.
Porphyry.
Granite.
Protoginyte.
Granite.

Granite is mentioned twice, as we find two distinct granite groups in Colorado.

With reference to diorite, euphotide, and porphyry we may say that, essentially, they stand in no direct relation with sedimentary formations. In the case of porphyry we have one instance in the Sangre de Cristo Mountains, where it has broken through Carboniferous strata. With this exception we may consider these rocks as pertaining more particularly to the metamorphic series. We find dikes and large eruptions of them within the metamorphic areas. Fortunately they are usually so placed that no mistake can be made as to their identity, which otherwise might become a matter of serious difficulty. It may be stated that granites, probably of plutonic eruptive character, are associated at times with euphotides.

It seems very difficult to assign any definite age to the rocks of these groups. So far as can be determined from association with sedimentary groups, their age may be regarded as Post-Carboniferous. All evidence in Colorado points to the fact that only unimportant stratigraphical changes took place before the close of the Carboniferous or even Triassic period. From this it may be inferred that the anarhactic and other eruptives, that we must regard as the oldest in Colorado, were synchronous with the first main disturbances. In view of these facts we can, perhaps, most correctly state that they must be considered as Post-Carboniferous and Pre-Cretaceous.

The older granites and protoginytes occupy prominent positions, and from their associations afford some indications as to their absolute age. We have observed that mainly Carboniferous and older beds were affected by the upheaval of the northern Sangre de Cristo Range. Evidently the rise then effected was sufficiently great to exclude the transmission of Cretaceous waters directly westward. A possibility presents itself that at the period of Cretaceous invasion the more easterly por-

tions, now covered by beds of that formation, were too low to admit of greater extension of the waters. In this case the subsequent rise of the entire region elevated such strata to their present position. We have, however, in the Sangre de Cristo Range tangible evidence in the severe disturbances to which the Carboniferous beds have been subjected. Evidence is adduced from various points there observed, that the upheaval of the granite was in the most intimate connection with the dislocation of Carboniferous strata. From the nature of these dislocations it must be inferred that the strata had already assumed a rigid stability. It can be said, therefore, that the eruption of members of this group must have been subsequent to the last deposition of Carboniferous beds.

More applicable results can be obtained from the study of the younger eruptive granites. Throughout the Elk Mountains, where they mainly occur, their associations with sedimentary beds are thoroughly constant. They have there been sufficiently well studied to arrive at satisfactory conclusions regarding the period of time when the granitic masses were erupted. In previous pages the contortion, plication, and upturning of Cretaceous strata in and near the Elk Mountains have been alluded to. We have, therefore, in this instance, phenomena whereby to measure the time of eruption. This falls, as nearly as can be determined, after the end of the Cretaceous period, reaching a time either in the Tertiary or after the close of the Cretaceous formation. Such is the accepted view of those who have studied the groups most carefully. There seems to be some connection, not only as to time, but also in composition and certain modes of appearance, between this series of granites and the next group, the trachorheites. Certain connections can be traced in a number of points between these two classes that bring them very closely together as regards genesis. Different conditions of cooling may produce such results that necessarily the rocks must at present be separated, although their former relations may be very apparent.

Of greater variety are the volcanic eruptive rocks of Colorado, an enumeration of which will give the following result, beginning with the oldest:

Trachorheites: { *Andesite.* *Trachyte.* *Rhyolite.* }
Porphyritic trachyte.
Dolerite.
Basalt.

This series can appropriately be divided into three groups. Of these the first—trachorheites—is the most extensive. In discussing this important group the direct relations to sedimentary strata have been given. On the eastern side of the trachorheitic area no favorable outcrops were observed. Along the western and southwestern edges, however, satisfactory evidence was obtained. We there find the trachorheites resting upon Middle Cretaceous shales. These latter have been removed from their original places of deposition, and the volcanic layers have been spread out over them. This assigns to the entire series an age falling near the close of the Cretaceous epoch. Isolated occurrences show rocks belonging to this group superincumbent upon Post-Cretaceous lignitic beds. Such relations decrease the age of trachorheites, bringing them essentially within the scope of the Tertiary period. This, too, is the accepted age for the analogous rocks of other countries.

So far as can be determined the various members of the trachorheitic series form one continuous chronological succession. We can, therefore,

accept the geological age above given for the entire group. Inasmuch as the ejection of the entire mass must have occupied a very long period of time, it is eminently probable that it commenced within—for instance—the Cretaceous and ended during the Tertiary period. We can safely place the age at that period, therefore, synchronous with which we observe the most recent volcanic effects.

Undoubtedly we must exercise considerable latitude for the chronological limits within which to confine any period of volcanic activity. It is evident that while the eruptions were going on, there was a continued deposition of sediment, which, by its organic remains, may now be referred to either one or the other conventional formation. We cannot, therefore, say definitely at which time the volcanic activity commenced, and we can only say approximately when it ceased.

The second group, that of the porphyritic trachytes, has been discussed at some length above, and its age has been regarded as having the same most recent limits as the trachorheites.

The youngest group, that of the basaltoids, is one that forcibly reminds the observer of lavas of the present day. From all the associations, of both dolerite and basalt, their absolute age can unequivocally be placed within the Tertiary epoch. Within the large areas less can be learned, as a rule, but the anarhactic and some of the isolated eruptives afford definite information. It has been stated in previous pages that the doleritic breccia of Middle Park is associated with beds belonging to the lignitic series, while a number of basaltic outcrops were observed in Tertiary strata belonging to the Eocene group. Frequently the "fresh" appearance of the basalts has been remarked upon. Dr. Peale says,* in speaking of the basalts occurring near Eagle River: "The basaltic rock is destitute of vegetation and comparatively free from soil. It has the appearance of having just been poured out. The period during which it was poured out is probably to be measured by hundreds of years, and perhaps less, rather than by longer periods."

From our present knowledge of the basalts of the West, we may say that they effect a transition from the prehistoric to the eruptives of the present day.† Evidences of this fact, far more striking than in Colorado, are observed in adjacent States and Territories. In subsequent pages allusion will be made to such instances.

With reference to the ages of these eruptive groups, as compared among themselves, we may say that the chronological succession is a well-established one. We are enabled, from the extended series of observations that have been made, to correlate the various members and arrive at definite conclusions as to their proper relative positions. An exception to this rule is made by the porphyritic trachytes. Their position in the chronological scale has been discussed previously, and a mere mention of the fact may here suffice.

A classified arrangement of the Colorado eruptives, so far as known and explored at the present time, is here presented. Classification is based upon the principles given in the introduction of this paper, and their grouping is made with especial reference to the results obtained in Colorado.

Plutonic:

BASIC:		ACIDIC:	
Diorite. Euphotide. Porphyry.	*Post-Carboniferous.*	Granite. Protoginyte.	*Post-Carboniferous.*
		Granite.	*Post-Cretaceous.*

* Rep. U. S. Geol. Surv , 1874, p. 172.

† Compare Rep. U. S. Geol. Surv., p. 222.

Volcanic:

BASIC: ACIDIC:

TRACHORHEITES:
- Andesite.
- Trachyte.
  - Trachyte No. 1.
  - Trachyte No. 2.
  - Trachyte No. 3.
  - Trachyte No. 4.
- Rhyolite.

} *Post-Cretaceous.*

Porphyritic trachyte Tertiary?
Symmorphic trachyte.

Dolerite. Basalt. } *Tertiary and Post-Tertiary.*

COMPARISON OF ERUPTIVES OF COLORADO WITH THOSE OF OTHER REGIONS.

Although, generally speaking, the occurrences of eruptive rocks in Colorado may lay claim to being unique, they have many points in common with those of other localities. Any comparison destined to establish similarity of the groups must necessarily fall somewhat short. This is due in part to the fact that technical nomenclature upon this subject is one that will bear very thorough revision and correction. Richthofen has succeeded in establishing definite terms for certain groups of our Western country. In the preceding pages the primary classification as proposed by Bunsen has been used, and subdivisions based upon, primarily, genesis, secondarily chronological succession have been applied. I am of the opinion that a classification of this character is certainly the most acceptable that could be utilized in the present instance. Though the chronological succession is a method of separation that can lay no direct claim to being one of strictly scientific character, it is the most convenient manner of distinguishing certain groups. Wherever the evidences of geological age are so perspicuous as in Colorado, a system of this kind will answer admirably well.

We find, upon examination, analogies to nearly all of the erupted rocks observed in Colorado. Far more prominent than in this State are the plutonic eruptions of Europe. There the series is well developed, and its members enter very largely into the geological structure of various regions. Diorite, euphotides, and that class of rocks that is comprised under the general name of gabbro, build up high mountains and even mountain-systems. In Colorado their appearance as well as their importance is generally subordinate. Eruptive granites, widely ranging in age, form a prominent feature of study for European geologists. Not only have they broken through sedimentary beds, but they have intruded into the older metamorphic rocks. Famous among many cases of this kind is that of Heidelberg,* where a fine-grained granite occurs, intrusive in a coarse-grained one. By the force of its intrusion the latter has been thoroughly brecciated and shows the altering influences of the younger mass.

Successively we find in Europe granites that range in age from Silurian to Tertiary. It is highly probable that the eruptions of the Elk Mountains vary but little in geological age from those observed in the Tyrol,† where granite has penetrated undoubted Tertiary strata. It may be well to devote here a few words to a subject that, in this connection, becomes one of great importance. We are accustomed to term that rock a granite, for instance, which proves to be a crystalline aggregate

* Cotta, Geologische Bilder, Leipzig, 1871, p. 196.
† Compare Cotta, Geologie der Gegenwart.

of feldspar, quartz, and mica. This definition is totally independent of any varying form of genesis or method of appearance. From the information that we have gained through the study of erupted rocks it seems eminently probable that varying results may be derived from the same original *magma* by different methods of cooling. To present an extreme case, we may assume that the same magma can, in one instance, be productive of the formation of high silicates mainly, while if cooling under different circumstances the silicates may be lower and free silica from the complement. If we speak, therefore, of eruptive granite, we mean to denote a rock that to-day has the mineralogical constitution of granite, totally irrespective as to what its previous condition may have been. What effects are in reality produced by the different methods of cooling we are unable to say. Certain experiments point to one view, others to another. It becomes a matter of great difficulty to arrive at definite conclusions from investigations that must necessarily be carried on on a small scale, when we desire to apply the knowledge thereby gained to masses of enormous proportions.

Proceeding to the remaining eruptives of Colorado we find that the adopted scale is more completely filled than by the preceding groups. An important member of the series—propylite—has not been recognized in Colorado. Richthofen has found it well developed farther west, and in Transylvania it plays a very prominent part. The propylite of Offenbanya was originally named "timazite" by Bielz. It is the rock containing the telluride ores of Transylvania. Cotta* states that he regards its age as younger than Eocene. His evidence for this assertion is derived from the fact that the same ore-bearing veins traverse the timazite and Eocene sandstones. In Nevada and adjacent regions the rock has been found, and is regarded by Richthofen† as older than andesite. With reference to this latter term there is some confusion, unless it be limited, as has most recently been done. The name was originally applied to all the volcanic rocks of the Cordilliera system, and not until a short time ago has its application been clearly defined. Andesites occur in the volcanic regions near Colorado, occupying a definite geognostic position. They are younger than propylite, older than the trachytes.

Trachyte is a name that has been very indiscriminately applied to many light-colored volcanic eruptives. Within its scope have been placed the volcanics of Transylvania, of Germany, France, and, to a large extent, of our western continent. Varieties have been based upon the predomination of one or the other inclosed mineral. Thus oligoclase, sanidine, and amphibole trachytes have been distinguished. Although the presence or absence of one or the other of these minerals is undoubtedly of systematic value within the circumscribed areas, no rule can be established that would answer in all cases.

Hauy first gave this name to the volcanic rocks of the Auvergne. Trapp-porphyry was adopted for the same rocks. L. von Buch gave that group of trachytes occurring near Puy-de-Dome the name domite. Beudant, who made the first extensive examinations of the volcanic regions of Transylvania and Hungary, separated the eruptives into four groups:‡

Trachyte,
Porphyre trachytique,
Perlite, and
Porphyre trachytique molaire.

* Treatise on Ore Deposits, Prime. New York, 1870, p. 277.
† Mem. Cal. Ac. Sci., 1868, vol. i, part ii.
‡ Beudant, Voyage Minéralogique et Géologique en Hongrie, 1822, Tom. iii, p. 310.

From his descriptions the first agrees with our present trachyte, and the second with rhyolite. Perlite is of subordinate importance, and the fourth probably indicates a variety of rhyolite. Timazite he has evidently included in his trachyte.

In Germany the volcanic rocks of the Drachenfels and other regions allied to it have passed under the names of trachyte and trachyte-tuffs. A variety of trachyte occurring in Silesia has been named teschenite by Hohenegger.* It is composed of amphibolite, augite, nephelite, and triclinic anorthite. Its age is regarded as being Eocene.

Throughout the Western country the application of the name trachyte is becoming more and more restricted. For the case that it may be impossible or inexpedient to separate the most closely allied rock-species, I have introduced the more comprehensive term of "trachorheite."

Trachyte occurs in large masses not only in Colorado, but also in other States and Territories of the West. Numerous varieties might be distinguished by special names, but there would be no end to the treasures of nomenclature were such separations attempted at the present time. A characteristic of trachyte is the constitutional change it may undergo within a very limited space. King describes an instance of this kind from the vicinity of the Comstock Lode.† He says, "It is of the sanidin variety," . . . . . . "partly a pinkish breccia, very loose in texture, and partly of a grayish, shaly sandstone mass, which is unlike any of the trachyte forms observed in the Great Basin," . . . . "but, as it approaches the main trachyte, becomes more and more crystalline, and passes imperceptibly into the ordinary variety, without any apparent junction line. Certain specimens cannot be separated from metamorphic sandstones." Such occurrences are not rare within the trachyte areas, and their explanation may most properly be sought in the different methods of cooling. It remains to be observed whether the character of the rock is such as has, in previous pages, been designated as symmorphic.

It has been an impossibility for me to find any definite analogy for what I distinguish as trachyte No. 4. Its similarity to timazite, both as a rock and in its associations, has been pointed out, but its geological position precludes the assumption of any identity.

Important as a portion of the entire series are the inclosures of the trachyte. No applicable rule governing their distribution can be given. In Colorado and elsewhere obsidian, pumice, and pitch-stone are characteristic of the trachyte group. Occurring in nodules or bands, they impart a peculiar habitat to the rocks containing them. Varying in composition from their immediate surroundings, they vary also in structure. Allusion has above been made to the concentric structure of a dike of obsidian observed in 1873.‡ An analogous case occurs in Bohemia, near Teplitz,§ where porphyry shows concentric arrangement, and weathers so as to simulate a half-opened rose. Whitney has observed similar conditions near Old Carson Pass.‖ There basaltic lava has been poured out over metamorphic granite. Through the action of heat, and probably pressure, the latter "has a concentric structure developed in it."

Porphyritic trachyte is a term which has first been applied by Mr. Marvine to a definite type of eruptives in Colorado. In speaking of Park

* F. Roemer, Geologie von Oberschlesien. Breslau, 1870, p. 363.
† Geolog. Expl. 40th Parallel, vol. iii, 1870, p. 36.
‡ Rep. U. S. Geol. Surv., 1873, p. 345.
§ Cotta, Geologische Bilder. Leipzig, 1871, p. 187.
‖ Geol. Surv. Cal., 1865, vol. i, p. 447.

View Mountain,* he applies that name to the rocks composing a number of dikes. Since that time it has been used when speaking of that peculiar type of eruptives whose existence was first demonstrated in Colorado. The term is by no means a new one, but the "porphyritic trachyte" of former geologists has been superseded by liparite.† This name, therefore, may be applied to the group under consideration, and, inasmuch as it is inverted from the usual trachyte-porphyry, may be claimed as a good, specific term.

In Europe no erupted mountains have been found, so far as I am aware, analogous to those formed by the group of porphyritic trachytes in our own country. They have been studied very carefully and successfully in Colorado by various members of the United States Geological and Geographical Survey. Since 1873 their structure and importance in the geological history of the regions has been recognized. As the survey progressed, one mountain-group after the other was visited, until to-day we are enabled to present a thorough analysis of distribution and structure. There is scarcely any one group within the limits of Colorado that affords so inviting and remunerative a subject of study. It has been found that the same class of mountains—referable to this group—that occurs in Colorado extends west and south. The Sierra La Sal and Sierra Abajo in Utah and the Sierra Carriso in Arizona furnish evidence of this. Mr. Gilbert has studied, within the past few years, the Henry Mountains. From his brief account‡ it appears that the occurrences there are in strict conformity with those we have observed in Colorado. He says: "The strata arch over the crest in a complete dome"; . . . . . . "the top of the dome has cracked open, and tapering fissures have run out to the flank, and they have been filled with molten rock, which has congealed and formed dikes." . . . . . . "So the mountain (Mount Ellsworth) is a dome or bubble of sedimentary rocks with an eruptive core, with a system of radial dikes, and with a system of dikes interlaced with the strata. It is a mountain of uplifted strata, distended and permeated by eruptive rock."

From a description of the Chisos Mountains, given by C. C. Parry,§ it may be inferred that they belong to the same class of eruptives. Wherever they have been observed their character is so definite that, once recognized, they can never be mistaken for any others. No doubt subsequent explorations of New Mexico, Arizona, and Utah will develop the fact that the horizontal distribution of this interesting group is not so circumscribed as it now appears to be.

Rhyolite is the remaining member of this class of rocks. Among all of them this one has, perhaps, most frequently been the recipient of misappellations. Its mineralogical constitution brings it into close connection with the older porphyries. What has been described as quartz-porphyr from Transylvania is mostly rhyolite. Beudant has termed it porhyre trachytique. Dacite is another name applied to the Hungarian occurrences. Rhyolite is the name proposed by Richthofen; nevadite is one of his rhyolitic varieties. Although sufficiently well represented in Colorado, it finds its greatest development farther west and south. Regarding its age there is no serious disagreement in the observations made. It is younger than trachyte, older than basalt. The case produced by Mr. Marvine, where, at Truxton Springs, Arizona, basalt was

* Rep. U. S. Geol. Surv., 1873, p. 174.

† Compare Cotta, Geologie der Gegenwart. Leipzig, 1872, p. 54.

‡ Rep. on Geol. of the eastern portion of the Uinta Mountains, by J. W. Powell, 1876, p. 20.

§ Rep. U. S. and Mex. Bound. Surv., W. H. Emory, 1857, vol. i, part ii, p. 56.

found overlying rhyolite, is one that certainly invites attention, but cannot seriously affect the position which is generally assigned to rhyolite.

This rock presents many varieties. At times it resembles a typical porphyry, showing a solid paste with numerous crystals imbedded therein, and again it will assume the form of a crystalline aggregate. Whitney* cites an instance of this kind. Near Lassen's Peak there is an occurrence of nevadite. "It has a resemblance to granite, so that, at a distance and without close examination, it would be taken for that rock."

An important feature of rhyolite was discovered by Dr. Loew.† He found that nearly all the rhyolites he examined contained either traces or small quantities of nickel and cobalt. He determined it as being in the form of oxide. The largest quantities he obtained were out of specimens from

	Gila River.	Sierra Caliuró.
Nickel oxide	0.03 per cent.	trace.
Cobalt oxide		0.02 per cent.

Usually it is found only in traces, however. This fact established a curious connection between the rhyolites and meteorites. Nickel and cobalt may be classed among the metals of comparatively rare occurrence. J. Lawrence Smith states‡ that he has made over one hundred different analyses of meteoric iron, and never failed to find cobalt. It is evident that in the ordinary course of a rock-analysis both cobalt and nickel would most likely be lost, so that we may safely infer that the rhyolites examined by Dr. Loew were not exceptional cases, but may rather be regarded as expressing a usual ingredient.

One of the most widely-distributed volcanic rocks is basalt. Frequently we find dolerite associated with diabase. This latter is of very little importance in Colorado. Both south and west, however, it has been found. Mr. Gilbert mentions a sanidin-dolerite from the San Francisco Mountains, which evidently occurs in considerable quantities.

All the world over rocks have been found that are referred to basalt. A number of varieties have been distinguished, dependent mostly upon the presence or absence of some characteristic mineral. In the most ancient times basalt was evidently mistaken for the highly-prized lydite or basanite. According to Ouenstedt,§ the present name is the result of an error committed by a copyist during the fifteenth or sixteenth century. The transition from basanites to basaltites, the old name, is not a difficult one.

In every respect is the position and character of basalt so thoroughly recognized that no reference need be made thereto. We have seen that in Colorado large areas are covered by it, and we know of its existence almost throughout the entire Western country. Its age, so far as Colorado is concerned, is readily established. In other regions, however, basalt sometimes bears totally different relations to surrounding sedimentary beds. Geike|| claims that the melaphyrs in Scotland are of Carboniferous age. The basaltic dikes in the granite of the Sweetwater region¶ are evidently not of Tertiary age, but older. Other instances

* Geol. Surv. Calif., 1865, vol. i, p. 315.
† Expl. and Surv. west 100th Mer., 1875, vol. iii, p. 646.
‡ Am. Jour Sci. and Arts, 1870, No. cxlvii, p. 331.
§ Compare Ouenstedt, Handbuch der Mineralogie.
|| Geolog. Magazine, London, 1870, p. 136.
¶ Compare Rep. U. S. Geol. Surv., 1870.

might be cited, simply showing that the conditions necessary for the formation of that product which we call basalt existed long before the advent of the Tertiary epoch.

For Colorado we can accept, as a rule, a Tertiary age for basalt. Several exceptions seem to occur, however. We have in basalt the volcanic eruptive which connects the prehistoric eruptions of our continent with those of the present day. In previous pages reference has been made to a statement by Dr. Peale, suggesting that the time of the eruptions might rather be measured by several hundred years than by long periods of time. All geologists who have explored the Western States and Territories speak of the remarkably fresh appearance of a large quantity of the ejected material. In speaking of Utah volcanics Dr. Engelmann* says: "The mineralogical character of the rocks seems to indicate that their formation began prior to the Tertiary period and continued to the present era." Mr. Gilbert gives a description of some very "fresh" specimens of lava and scoria from the Lower Sevier Valley in Utah.†

In New Mexico a number of localities occur where the lava is similarly fresh. Dr. Newberry in discussing Mount Taylor‡ says: "The lava-streams of its latest eruptions present precisely the same appearance as those of Vesuvius when but just cooled." His examinations of the San Francisco Mountains revealed to him the same state of affairs. If possible the condition here is even more striking. Newberry states:§ "Some of the currents of lava which have flowed down the sides of the San Francisco Mountains belong so entirely to the present epoch that they have dispossessed still running streams from their beds, and now occupy their places in a congealed flood which seems but just arrested in its flow."

As we advance from what may be considered as interior land toward the Pacific Ocean, or, with other words, as we leave the Rocky Mounttains and reach the coast-ranges, we find still more positive evidence ot the recency of volcanic eruptions. Coincident with the increasing quantity of points of eruption and with the younger age, we find that the characteristic of "massive" eruption is gradually disappearing, and "volcanic" eruptions take their place. This necessarily results in the formation of crater-cones. Mr. Gilbert‖ has found three perfectly distinct craters at Ice Spring, near Fillmore, in Utah.¶

Among the mountains of Washington Territory and Oregon, as well as in California, we find more than one still showing signs of volcanic action. Prominent among these is Mount Shasta. Professor Whitney finds** near the summit of this peak "the remains of the edge of the crater," where "there are several orifices from which steam and sulphurous gases are constantly escaping, and around which is a considerable deposit of sulphur, some of it being handsomely crystallized." It may, in truth, be called a small solfatara. Similar conditions occur near Mono Lake, about which Whitney says:†† "To the north lies a group of islets;" . . . . "there is every indication that the volcanic action has ceased at a very recent period, or, rather, that it has not yet fully died out." . . . . "This portion of the island is of hard, black

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* Rep. Expl. across the Great Basin, by Capt. J. H. Simpson, in 1859, Wash., 1876, p. 307.

† Expl. and Surv. west 100th Mer., 1875, vol. iii, p. 566.

‡ Rep. Expl. Exp., 1859, J. N. Macomb, 1876, p. 61.

§ Rep. upon the Colorado River of the West, J. C. Ives, 1861, part iii, p. 66.

‖ Expl. and Surv. West 100th Mer. 1875, vol. iii, p. 138.

¶ Compare: Proc. Am. Ass. Adv. Sci., Hartford, 1874, p. 29.

** Geol. Surv. Calif., vol. i, 1865, p. 340.

†† Ibid., p. 453.

basalt, with some scoriæ and cinders." . . . . "The steam and hot gases escape from hundreds of vents, and often with considerable noise."

Another very prominent mountain of the northwestern corner of the United States has been found to show similar conditions. An ascent of Mount Rainier, which is nearly 14,500 feet above sea-level, was accomplished by A. D. Wilson and S. F. Emmons in 1870. In a paper read by Mr. Emmons, in February, 1877, he describes the ascent.* It was found that the summit of this peak was formed by an ancient crater-rim, and that on the interior rim there were numerous hot jets of steam issuing from under the snow.

Many other instances of this kind might be mentioned, but these will suffice to show the almost imperceptible connection between the rigid basalts and others, indicating dormant volcanic activity. These latter are gradually dying out, and within, perhaps, a few centuries no hot jets or gases will any longer mark the spots where now we find the last lingering remnants of a former volcanic activity.

Following northward, parallel with the extensions of the coast-ranges, not within the Rocky Mountains, we reach still active volcanoes. In the Alaskan Range a number of them are located.†

It is almost an impossibility to draw the line between what might properly be termed basalt, and what must be regarded as still partly active volcanic material. I am not prepared to restrict the occurrence of basalt to a period not prior to the Tertiary, and have no objection to leave the younger line of boundary equally ample. Cotta contends‡ that no bowlders of true basalt or trachyte have ever been found in Europe in Pre-Tertiary conglomeritic deposits. This would argue an inference directly in opposition to the view of Gieke, which has been given above. From the observations made on the Sweetwater River, in Wyoming, I cannot arrive at any other conclusion than that basalt existed as such before the advent of the Tertiary period.

In connection with the basalts, I wish to mention the occurrence of a rock discovered in the Green River Basin. In want of a better name, I shall apply that of "leucitophyrite." The leucitophyrs of Italy differ somewhat from that observed in the Green River Basin. Emmons states§ that the rock is composed of a light-gray to greenish porous paste, with some mica. Under the microscope the entire rock is resolved into leucite. With reference to its age, Emmons says it has been poured out "not only since the deposition of the later Tertiaries (*Green River and Vermillion Creek Groups*), but since their partial removal by erosion." We have, therefore, in this instance a volcanic rock, the eruption of which must have fallen into a period of time during which a portion of the basalts were ejected.

In order to present a synopsis of the systematic arrangement of the volcanic eruptives of the Western portion of the United States, I have prepared a table showing their relative positions and giving synonyms as applied to the same rocks in other countries.

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* Bulletin No. 3, American Geogr. Soc. New York, 1877.
† Alaska and its Resources, W. H. Dall., 1870, p. 286.
‡ Geologie der Gegenwart, Leipzig, 1872, p. 133.
§ U. S. Geol. Expl. 40th Parallel, vol. ii, 1877, p. 236.

Table showing the classification of volcanic eruptives for the Rocky Mountains and adjacent regions.

NOTE.—Those occurring in Colorado are printed in SMALL CAPS, and the synonyms for other countries in *italics*. The arrangement begins with the oldest group.

VOLCANIC ERUPTIVES.

BASIC:

Propylite.
 Syn.: *Timazite*, Hungary.
 Grünstein-trachyt of German geologists.

ACIDIC:

ANDESITE.
 Syn.: *Andesite* of the Cordilliera system.
TRACHYTE:
 TRACHYTE No. 1.
 Syn.: *Trachytic tuffa, trachyt-tuff* of Germany.
 TRACHYTE No. 2, and
 TRACHYTE No. 3.
 Syn.: *Sanidine* and *oligoclase trachyte*. *Domite* of the Auvergne. *Trachyt* of Germany. *Trapp-porphyr* by Buch. *Trachyte* by Beudant, of Hungary. Inclosures of these trachytes are: *Perlite, obsidian, pitch-stone*, and *porphyritic pitch-stone*.
 TRACHYTE No. 4.
RHYOLITE.
 Syn.: *Nevadite* of Western regions. *Rhyolite* and *dacite* of Transylvania. *Quartz-porphyr* of older German geologists. *Porphyre trachytique* of Hungary, by Beudant.
PORPHYRITIC TRACHYTE.
 In the present acceptation this has no synonym. *Liparite* expresses what formerly was termed porphyritic trachyte.

BASIC (continued):

Diabase.
 Syn.: *Trapp* of Germany and Eastern States.
DOLERITE.
 Syn.: *Trapp*. Varieties are termed *nephelindolerite* of Germany, and *sanidine-dolerite* of New Mexico.
Leucitophyrite.
 Syn.: *Leucitophyr* of Germany and France; *leucite-rock* of Green River Basin.
BASALT.
 Syn.: *Trapp* of Germany and Eastern States. Varieties of basalt are *melaphyr*, &c. Inclosures: *Olivinyte*, &c.

ORIGIN OF ERUPTED ROCKS.

At the close of the description of the erupted rocks of Colorado, a brief discussion of the origin of such material may here find its place. It is natural that the study of the products of plutonic and volcanic activity will create in the mind of every student some conception as to the forces to which such products owe their existence and present position. It is equally natural that every individual mind may grasp more particularly one point observed that might have escaped the attention of others. Thus the result evidently will be that each writer on the subject will show a personal coloring illustrative of the predominant direction towards which his views incline. It is not my intention to present, at the close of this paper, an exhaustive review of the vari-

ous hypotheses and theories tending to explain the phenomena of dynamical geology. An outline will be given of the suggestions that have offered themselves from the examination of the eruptive rocks of Colorado. In case subsequent investigations may prove the inductions here derived from observation to be correct they can readily be applied to other localities.

In any discussion upon the probable source of volcanic activity, we must take for granted the high temperatures existing within the interior of the earth. These are universally conceded, and amply demonstrated by facts. It is essentially immaterial whether we assume that the interior of the earth is in a truly liquid state, or whether we regard its condition as merely plastic. Of these the former hypothesis is inconsistent, however, with the absence of internal tides, in case we assume the earth's crust to be a thin one as compared to its entire diameter. No observations tend to show that such tides exist.

Formerly the central liquid or plastic state of the earth's interior was regarded as furnishing the material for volcanic eruptions. More comprehensive observations and a more thorough knowledge of the characteristics of volcanoes have led to the abandonment of this theory. It is now assumed and the assumption is accepted by most geologists, that certain circumscribed portions beneath the earth's surface that must still be regarded as integral parts of its crust, are in a condition either approaching or actually exhibiting liquidity. From such portions which may aptly be designated as "reservoirs," is derived the material ejected during volcanic eruptions. No means are at hand to establish, definitely, any depth at which they should occur. From phenomena attending volcanic eruptions, however, it may be inferred that they are located at a depth that must be regarded as shallow when compared with the entire diameter of the earth. Seismic action is one of the most characteristic results of disturbances of equilibrium occurring within certain regions or zones of the earth's crust. The prevalence of earthquakes at any given locality furnishes a criterion as to the relative condition of underlying portions of the crust. Most frequently they may be observed in regions that are the scene of volcanic activity, but they extend far inland from any present point of volcanic eruption. A definite relation may frequently be traced between seismic occurrences of one section and eruptions of the nearest active volcanoes. A rather striking example is afforded by a comparison of the slight earthquakes felt in Switzerland and the eruptive activity of Vesuvius.

From the act of eruption and from the products thereof we can gather only rather general views as to the origin of and the causes producing it. The ejection of lava is usually accompanied by the discharge of watery vapor, of carbonic and hydrochloric acid gases, and hydrogen, both free and in combination with sulphur and carbon. These elements or compounds have not all entered into the composition of the lava to any extent, but occur independently thereof. Reducing all of them to their original elements, we find:

Hydrogen,
Oxygen,
Nitrogen,
Chlorine,
Carbon, and
Sulphur.

Of these, oxygen, carbon, and sulphur are most frequently observed in the lava itself. Direct oxygen compounds and silicates make up the

largest portion of the lava. Carbonates, sulphurets, and other combined forms occur comparatively sparingly, and must be regarded, in many instances, as epigene products.

From the evidence adduced by erupted material, therefore, we can infer that those portions of the earth's crust which furnish the ejected masses are composed of direct oxygen compounds and silicates mainly. These two classes make up by far the largest proportion of the crust, so far as it has been possible to study it. Several of the elements must, therefore, be accounted for: hydrogen, nitrogen, chlorine, carbon, and sulphur. In attempting to explain the presence of these elements at very considerable depths, we touch upon a subject which, in this connection, becomes one of the utmost importance. This is the subject of infiltration.

The emission of water during volcanic eruptions has been a subject of careful study. From the fact that active volcanoes are found almost exclusively in the vicinity of large bodies of water, the hypothesis has been derived that they are in direct connection with such bodies. A number of theories have been advanced explanatory of the method whereby the water could find access to the regions of high temperature. Others have assumed that the aqueous vapors emitted were merely the equivalent of precipitated moisture or of direct leakage. Either one of the views undoubtedly expresses a portion of the truth. It is eminently probable that water precipitated in the immediate vicinity of volcanic vents may find its way, as drainage, to such depths, from which it will be ejected by force. On the other hand, fissures, in connection, perhaps, with standing bodies of water, may conduct a certain amount of it to the upper portions of the liquefied rock. Besides these sources, however, we have that of the perpetual percolation of water to great depths. It is an accepted theory that water penetrates the rocks composing the earth's crust to a far greater depth than has been reached by man. We have here, then, a prolific source of oxygen and hydrogen. Carbonic-acid gas is equally assumed to penetrate to very great depths. As a concomitant of water it is well known. Sulphates and chlorides can be found in aqueous solutions, and chlorides are the main mineral constituents of sea-water, readily held in solution. Sir H. Davy and others have assumed the presence of atmospheric air in volcanoes, occurring at depths sufficiently great for the purpose of decomposition. We have, therefore, in the afflux of water and the compounds it usually holds, either in solution or mechanical retention, the means of explaining the presence of all gaseous elements or compounds observed in connection with volcanic eruptions.

Having thus briefly alluded to the evidence furnished by volcanic eruptions referable to admixtures that can be regarded as accidental, when compared with the lava itself, we proceed to the consideration of the causes producing such eruptions.

In the presence of water at depths where the temperature must show a very high degree, we have a factor that is capable of very great expansive power. Analogous to eruptions of geysers, the eruptions of volcanoes have frequently been regarded as being due to the change of water into steam. No more powerful agent, perhaps, could be imagined than steam for propelling through existing fissures the liquefied rock—the lava. Accepting the theory which seeks the origin of lava not in the central fluid or plastic masses of the earth, but in "reservoirs," more or less localized, it becomes incumbent to account for the liquefaction of those portions of rigid rock which have filled the reservoirs.

Numerous views, intended to explain the formation of such reservoirs

have been advanced. They have been regarded as portions that were, by some means, separated from the central fluid or plastic mass. Processes of chemical decomposition and formation of new compounds have been quoted as causing a sufficiently high degree of temperature to produce viscidity of the rocks. Pressure unequally distributed has been adduced as a factor capable of producing the same result.

So far as my investigations have led me, I have arrived at the conclusion that the formation of reservoirs containing liquefied rocks or, using the general term, lava is the result of primarily irregularly distributed pressure and chemical action. In order to present this view more clearly, I shall present a synopsis of the methods employed in producing the obvious result of volcanic eruption. First, I shall endeavor to point out those facts connected with pressure, and then the character of the chemical changes which the rocks undergo.

Charles Babbage conceived, in 1834,* that, in consequence of the changes going on at the earth's surface, changes produced by the removal and redeposition of portions of the solid rocks, the surfaces of "equal temperature" within its crust must be continually changing. As the result of such changes he concludes that "rents may be formed, mountain-chains raised, and even continents elevated." Recognizing very clearly the direct influence of such a change of equilibrium, Babbage has probably overestimated the extent of the results which might be produced. Two years later Sir John Herschell expressed similar views more fully in a letter to Charles Lyell.† He says: "Supposing the whole (*earth's crust*) to float on a sea of lava, the effect (*of accumulated sediment*) would merely be an almost infinitely minute flexure of the strata; but supposing the layer next below the crust to be partly solid and partly fluid, and composed of a mixture of fixed rock, liquid lava, and other masses in various degrees of viscidity and mobility, great inequalities may subsist in the distribution of pressure, and the consequence may be local disruption of the crust where weakest, and escape to the surface of lava." Essentially the same idea as expressed by Babbage, the view of Herschell presumes conditions which may partially be granted, and the results he deduces therefrom are in proportion to the original force employed. He states further that in case the process of sedimentation be continued to that point until "some support gives way," a portion of the solid crust breaks down, thus forming one or more vents for the ejection of liquid lava. Into the opening thus formed the liquid will rise by simple hydrostatic pressure. With increasing height of the column or sheet the pressure diminishes until a point is reached where the "ignited water" can become steam. Then the joint specific gravity suddenly diminishes, and there is violently forced upward a mixture of lava and steam.

In this way Herschell explains the production of volcanic eruptions as directly the result of pressure caused by accumulations of sediment. One of the main conditions essential to this explanation is the breaking of "some support." Though undeniably this may be supposed to occur, it is an occurrence that would probably result in a violent, short eruption, and not in one continuing for ages. Acceptable as this explanation of the origin of volcanic eruptions is, it has a bearing most directly upon a short, destructive series of ejections, rather than a long, continued one.

T. Sterry Hunt has, for a number of years, paid much attention to this question, and has furnished many valuable contributions thereupon:

* Proc. Geol. Soc. of London, 1834, vol. ii, p. 75.
† Proc. Geol. Soc. of London, 1836, vol. ii, p. 548.

* "We conceive that the earth's solid crust of anhydrous and primitive ingneous rock is everywhere deeply concealed beneath its own ruins, which form a great mass of sedimentary strata, permeated by water. These rocks, at a sufficient depth, are necessarily in a state of igneo-aqueous fusion, and in the event of fracture in the overlying strata, may rise among them, taking the form of eruptive rocks." Lyell† says: "The permanent elevation and subsidence of land now observed, and which has been going on throughout past geological ages, may be connected with the expansion and contraction of parts of the solid crust, some of which have been cooling from time to time, while others have been gaining fresh accessions of heat."

Such and similar views have been advanced to explain the sources from which the volcanic material might be derived. Taking a totally different ground are those explanations of the source of heat which are founded upon purely chemical bases.

Keferstein, in 1834,‡ contends that volcanic phenomena have their origin in sedimentary strata, and that they are the result of chemical changes there going on. As Hunt correctly remarks, § Keferstein has placed his hypothesis upon an untenable basis by "ignoring the incandescent nucleus as a source of heat." Bischoff, who made numerous experiments relative to the fusion of rocks, came to the conclusion that the presence of carbonic-acid gas at great depths would produce decomposition of the silicates. Carbonates would be formed in consequence, and the increase of bulk might readily produce mechanical uplifting of strata and other phenomena.

My friend, Capt. C. E. Dutton, has published a series of highly interesting speculations as to the earth's physical evolution.|| He takes the hydrothermal theory of metamorphism for granted, and assumes that the process is an intensified solvent power over silica, alumina, and other minerals. By this means the original combinations are broken up. He regards the results obtained with reference to the minerals as essentially the same as the soluble hydrates obtained in the laboratory. This production or change is accompanied by a large diminution of the specific gravity. Although the assumptions cannot be proved, as the entire nature of the process is not understood, we are enabled, judging from analogies, to conceive the possibility and even probability of such conditions as Dutton supposes to take place.

Making a careful survey of the most prominent hypotheses proposed, and eliminating such features as seem to me irreconcilable with facts observed, I have arrived at a series of results that are set forth in the subjoined pages. It will be necessary to revert to some questions already touched, for the purpose of a complete understanding of the views held.

Within the interior of the earth's crust we have certain definite zones of heat. To what degree the temperature may rise is immaterial. The distance of these zones from the centre of the earth will vary proportionately to the amount of pressure at any given point. In accordance with Herschell, we assume that the deposition of enormous quantities of sediment at any point, or along any line, will eventually produce a flexure or fracture of the underlying masses of rigid rock. This flexure or fracture will be expressed by a movement of the disturbed portions

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* Canad. Jour., May, 1858, vol. iii, p. 207.
† Principles of Geology, 1868, vol. ii, p. 242.
‡ Naturgeschichte des Erdkörpers, vol. i, p. 109.
§ Am. Jour. Sci., July, 1860.
|| Penn. Monthly, May, 1876, Philada.

towards the centre of the earth. Thereby the isothermal zones within the earth's crust will be changed.

For the purpose of illustration, we will take the zone of liquefaction. In case certain portions of the earth's crust are forced nearer towards the centre of the earth, there will be a tendency towards re-establishment of the disturbed equilibrium. Rocks and portions of rocks that have heretofore been in a rigid condition have passed the zone of liquefaction. Necessarily, this influx of heat-absorbing material will change the absolute limits of this zone. A portion of the intruding material will be liquefied; another portion will assume a higher degree of temperature; a portion may or may not retain its former conditions.

Primarily, additional pressure is exercised within this group by the rocks changing from rigidity to plasticity, and to viscidity. According to experiments by Bischoff, granite, for instance, loses more than 10 per cent. of its volume in passing from a melted or plastic condition to rigidity.* Reversing the proposition, we find that a rock representing the type that we might expect to find within the interior of the earth's crust gains more than 10 per cent. by being melted. This pressure, again, will exercise its influence in still further increasing the degree of heat, and will thus produce a viscous condition of some portions that otherwise would have remained plastic or perhaps even rigid. This influence will make itself felt within certain limits, defined by the quantity of originally remelted material.

In this manner we may assume that what have been designated as "reservoirs" are formed. In speaking of the condition of the earth's interior, the term "liquid or plastic" has been used in previous pages. Inasmuch as the questions involved did not directly affect this point, the term was thus used. It seems to me that the hypothesis, supposing the existence of a solid, anhydrous nucleus, and a liquid zone between it and the rigid crust, is not sufficiently well sustained to demand acceptation. More in conformity with phenomena observed, and better adapted for the support of many most important hypotheses and theories, is the assumption which regards the interior of the earth as being in a plastic, anhydrous condition. Between this anhydrous, central mass and the exterior crust lies a thermal zone containing disconnected areas of liquefied rocks. These are the reservoirs. Their extent is directly proportionate to the amount of accumulated sedimentation, and to the solvent powers of such agents as may be employed.

As solvent agents we may regard primarily the directly acting pressure, and, secondarily, the presence of water and other compounds. It seems eminently probable, and, so far as experimental knowledge goes, the supposition is supported, that water under great pressure and at high temperatures will act as a most powerful agent in breaking up the composition of minerals constituting the rocks at such depths. In this condition of hydrothermal solution we may assume that a hydration of some of the compounds, so far as they may still be individualized, will take place. Such hydration necessitates a decrease of specific gravity, an increase of volume. It is impossible to measure the quantities to which this would amount, because we are not able to reproduce, artificially, the conditions existing at the depths we are speaking of. Hunt says:† "The mechanical pressure of great accumulations of sediment is to be regarded as co-operating with heat to augment the solvent action of the

* Bulletin de la Soc. Geol., 2d series, vol. iv, p. 1312.
† Am. Jour. Sci. and Arts, vol. iv, p. 26.

water, and as being thus one of the efficient causes of the liquefaction of deeply-buried sedimentary rocks."

Conceding these views, we have a double action producing a decrease of specific gravity. We have the mechanical action produced by pressure, and we have the result of chemical changes of hydration. The pressure produced within the limits of the reservoir will tend to increase its size. As fresh, undisturbed zones are reached by the spreading action, new acquisitions of chemical solvent agents will be encountered. Heat will be lost in the conversion of this fresh supply from a rigid to a plastic or liquid condition. It is evident, therefore, that the enlargement of the reservoir will eventually reach a point beyond which it will progress but very slowly. Should the effects of superimposed sedimentation, which have gradually wrought this condition, cease, then, too, will the process of liquefaction progress no further.

In case the reservoir thus formed is sufficiently near the surface of the earth, the strain incident upon its generation will be entirely sufficient to produce seismic phenomena. These may be manifested simply by vibrations and concussions, or they may result in the formation of fissures. In addition to this method of forming fissures we are acquainted with many other modes. Perhaps one of the most striking is that suggested by Sir John Herschel, which has been given above.

At the time of the opening of a fissure or series of fissures we have, within the reservoir, certain definite conditions; a more or less homogeneous magma has been formed by the liquefaction of the original rocks; the mass is in the condition of maximum tension; water is held there at very high temperatures and under great pressure; gaseous vapors which have been reduced, even at such great heat, to liquidity may be retained within the limits of the reservoir.

Upon the opening of the fissure the viscous mass will rise into it by hydrostatic pressure. Should the lava then reach points where the conditions are no longer such as to retain water and liquefied gases in the same state as within the reservoir, these will suddenly expand, and, under favorable circumstances, produce the phenomenon of catastrophic volcanic eruptions. Where either the configuration of the fissure or the tension of the material within the reservoir are such as to preclude an occurrence of this character, we will have different results. Either the lava will ascend into the fissure until it flows over, with the demonstration of violent force, at the surface, or the lava will rise within the fissure until hydrostatic pressure and expansion of gases can no longer propel it upward. By the agency of heat, decomposition of water may take place, and the additional quantities that may be encountered on the way upward will be utilized to a certain extent. This feature seems to account for the presence of hydrogen and chlorine during volcanic eruptions of the present day, while nitrogen would be derived from the decomposition of atmospheric air which was enclosed within the fused masses.

Should the eruption be essentially a slow one, it may easily occur that the liquid masses will be cooled down sufficiently, and the conditions of pressure may be favorable to the sudden conversion of superheated water to steam, and liquefied gases to vapors at very considerable depths. This in turn would tend to restore the original conditions of equilibrium, which now would be abnormal. Continued deposition of sediment, the everchanging absolute position of the zone of liquefaction, and the attempted restoration of static conditions would eventually result in a repetition of the same occurrences. Fissures would again be formed at

the points and along the lines of least resistance, and fused rocks would be ejected within the same region successively for a long period of time.

All the phenomena which must be the inevitable resultants of such conditions and occurrences as are assumed above to take place, have been observed within the range of the study of vulcanicity.

As, perhaps, the primary conditions, we must regard the accumulation of sediment at any one point, or along a certain line. This will be most readily effected along the edges of large bodies of water. There we find to-day the best development of volcanic activity. Eruptions that belong to past geological periods may be found to have taken place in regions which were similarly situated. Near the borders of large bodies of water this liquid has the best opportunity of penetrating through rocks to the greatest depths. Hence it is there that we will find the best supply of so powerful a solvent agent. According to Scheerer* the "presence of 5 or 10 per cent. of water may suffice, at temperatures approaching redness, to give to a granitic mass a liquidity partaking at once of the character of an igneous and aqueous fusion."

Eruptions have been observed, showing the action of some suddenly-developed force, and islands have thus been formed, some of which have remained to the present day, while others, again, have disappeared.

As a rule, the rocks forming lavas do not consist of hydrated minerals. Exceptions are formed by many occurrences of quartz, however. Nearly always the matrix of semi-opal or opal has proved to be of undoubted eruptive origin. Here, then, we have an instance in which the water was retained as a component part of the primarily anhydrous mineral. It is highly probable that minerals—if retaining any individuality in the fused magma—and the magma itself have lost their water at that point when it was rapidly converted into steam. Generally, lavas show more or less porosity. This characteristic feature is evidently the result of gaseous enclosures. A large percentage of the enclosed gases must be referable to atmospheric air. But the vesicularity is often observed at such points where air could scarcely have had any access to the lava. Without assuming too much, then, the vapor producing this porosity may, in many instances, be referred to steam. Any gas of specific character would probably have produced such alterations of the immediate surroundings of its enclosing mass that its former presence could even now be detected.

The views above given were suggested by a study of the eruptive rocks in Colorado, and to my mind they offer perfect agreement with the observations that led to their present form.

ORIGIN OF THE ERUPTED ROCKS OF COLORADO.

In the year 1873, I was struck with the ultimate similarity of some of the metamorphic rocks and the trachorheitic eruptions observed in Colorado. I then published, without further elaboration, the opinion that I regarded the latter simply as the result of the fusion of granites†. At the same time, Dr. Peale came to similar conclusions. He suggests,‡ whether the eruptive granites of the Elk Mountains might not properly be regarded as a remelted metamorphic granite, and points out the possible establishment of a direct connection between the trachytes and the granites of that region.

The more I had an opportunity to study the eruptives of Colorado,

*Am. Jour. Sci. and Arts, T. S. Hunt, vol. 4, p. 26.
†Rep. U. S. Geol. Surv., 1873, p. 350.
‡Ibid., p. 261.

the more firmly I became convinced of the correctness of the hypothesis. We have in Colorado mainly the two great groups of volcanic eruptives, the trachorheitic and the basaltoid. Of these, I regard the former, together with the Elk Mountain eruptives, as remelted metamorphic granite, and the latter as the product of a series of hydrothermal fusions. In speaking of the trachytes of the Auvergne, Quenstedt says,* "The trachytes of the Auvergne, protruding from the granites, appear to be simply a granite altered by heat and devoid of its free quartz." Leopold von Buch, who made many careful examinations of that region, says: † "Granite is the original mass from which this lava has been formed."

The reasons for assuming such an origin for the trachorheites are:

(1.) They occur mainly within granitic areas. Although spreading in many directions over sedimentary beds, they start from metamorphic regions.

(2.) The similarity of composition of trachorheites and of granite upon ultimate analysis.

(3.) The enclosures of foreign granitic masses within trachorheites in various stages of fusion.

(4.) The definite ratio exhibited by trachorheites; the older ones presenting types that admit of ready fusion, the younger ones less so.

Taking into consideration the main area of trachorheites, we have been able to discover but one single point of outflow. This is located not far from Uncompahgre Peak.‡ This is located so that, although no metamorphics are exposed within the immediate vicinity, their existence there, unincumbered by sedimentary strata, is undoubted.

An interesting feature is that of foreign enclosures. They are of such a character that they cannot always be regarded as having existed on the surface at the time of the eruption, and having been enveloped by the lava, but as having been carried upwards along with it, from a point perhaps but very little removed from their sources. Dr. Loew has observed similar conditions in New Mexico. He says:§ "Here the rock (*rhyolite*) exhibits a close relation to the granite which it overlies, inasmuch as it encloses semi-fused fragments of the latter. Moreover, we can trace quite distinctly the effects of various degrees of heat upon masses of feldspar. . . . . . . It would appear that we here have a granite with partial transformation into a rhyolite. . . . . On the San Francisco, seven miles above its mouth, masses of rhyolite occur that contain through the whole particles of kaolin." Emmons mentions an analogous occurrence.‖ In the rhyolites of Washoe Mountains a specimen was found showing quartz which contained "a number of liquid-inclusions with mobile bubbles." Zirkel mentions that near this fragment of quartz he found a piece of decomposed feldspar, and comes to the conclusion that both minerals are "bodies foreign to the rhyolite."

An examination of about two hundred specimens of metamorphic granite from Colorado showed that none of them was without magnetite. Some contained considerable quantities.

Averages taken from, respectively, ten and thirteen analyses show the percentages of silica and ferrous oxide to be as follows, viz:

	Trachyte.	Rhyolite.
Silica	60.87	74.90 per cent.
Ferrous oxide	3.76	1.75 per cent.

* Epochen der Natur, 1861, p. 162.
† Mineralogische Briefe aus Auvergne, 1802.
‡ Compare Reps. U. S. Geol. Surv., 1874 and 1875.
§ Rep. Expl. and Surv. West 100th Mer., vol. iii, 1875, p. 641.
‖ Geol. Expl. 40th Parallel, vol. ii, 1877, p. 482.

It is to be regretted that not more analyses of other volcanic rocks were available, or we would probably be able to see the result; the trachyte does not contain the lowest average of silica of the trachorheitic group.

If we assume that the normal composition of a given metamorphic granite were identical with that of the trachyte, containing 60.87 per cent. of silica and 3.76 of ferrous oxide, and we subject that granite to a process of fusion and recrystallization, what would be the result? If we could produce such conditions that only a portion of the mass were to be fused at a time, and the entire quantity to be used up successively, we would probably find that those portions requiring the smaller amount of heat or the least powerful solvent agents would be separated first. This result would furnish us with the most readily-melting product, with the one containing the least silica and most iron. Repeating the process upon the same block with or without the admixture of new material of identical composition, we would obtain higher percentages of silica, smaller ones of ferric compounds. Such a process could be continued until silica no longer found sufficient quantities of other oxides to form silicates, and would make its appearance in the product of fusion as free quartz. Conditions analogous to this I assume to have occurred at the time of the genesis of the trachorheites.

From all evidence, the eruptions of the Elk Mountain granites were attended with greater demonstrations of violence than those of the trachorheitic areas. In that instance we may have a more complete, more rapid fusion of the original mass, and, in consequence, a crystalline aggregate upon cooling. How much effect the various methods of cooling must have had upon the lithological and mineralogical character of the molten material has been suggested in previous pages.

From the uniform character of the trachorheites it may be inferred that they have had their origin at comparatively shallow depths, within zones of similar rocks. Little or no violence attended their ejection, in conformity with the rule as pronounced by Cotta,* that the erupted masses rarely produce extensive mechanical or chemical changes. The ejection of lava has taken place through fissures. Although evidently in a highly viscous state, as a rule, it flowed for long distances, quietly leaving the opening through which it was brought to the surface.

Dissimilar in certain respects are the eruptions of porphyritic trachytes. Greater demonstrations of force are noticeable within their range. Either one or more reservoirs furnished the material for a group or cluster of groups. Their singular coincidence of structure argues for a common origin, and for identical mode of ejection. Breaking through the same beds at different localities, the lavas have met with the same obstacles, and, obeying the same forces, have produced the same results.

The basaltoid group represents types that I regard as having undergone more than one fusion. They contain a low percentage of silica and a high one of ferrous oxide. Although occurring isolated, the largest massive eruptions observed were in connection with other eruptions. I am aware that this is not always the case; but where it is not, I should regard the basaltoids as generally relatively younger. Exceptions to this rule are not wanting, however. Inasmuch as these rocks essentially form a transition to the lavas of the present day, their persistence as frequently fused masses receives additional proof. We can scarcely assume that the periodical ejections of lava, which we now observe, should always indicate the alteration of fresh material. We

* Geologie der Gegenwart. Leipzig, 1872, p. 128.

may rather suppose that certain portions are gradually cooled off, are again reheated to sufficiently high temperatures only to form comparatively low silicates, and are ejected as such.

This view bears directly upon the point of extinction of volcanic activity within certain circumscribed areas. Should the percentage of silica in the material of any one reservoir become so high, that the temperature and other solvent agents there existing are no longer sufficiently great to produce fusion, then a cessation of eruptions must ensue. In case no additional material is introduced within the range of the reservoir, this cessation will remain permanent. As the result we will find that all volcanoes or volcanic vents supplied therefrom must become inactive.

RECAPITULATION.

So as to present in concise shape the main conclusions drawn from the study of the eruptive rocks of Colorado, a short recapitulation is here presented.

I. The eruptive granites and trachorheites of Colorado are the direct products of remelting of metamorphic rocks, mainly granites.

II. With decreasing geological age of the trachorheites the percentage of silica increases.

III. The basaltoids are the products of repeated fusion and cooling of what originally were metamorphic rocks.

IV. The age of the oldest eruptives in Colorado, recognizable as such, falls into the Post-Carboniferous era.

V. The age of the Elk Mountain granites, trachorheites and porphyritic trachytes falls into a period subsequent to the close of the Cretaceous formation. Eruptions probably continued throughout the first half of the Eocene.

VI. The age of the basaltoids in Colorado falls into the Tertiary period, and in adjacent States and Territories it may be connected to eruptions of the present epoch.

VII. The main portion of the eruptions in Colorado was determined, as to horizontal distribution, by the arrangement of maximum Cretaceous and, in part, Tertiary sedimentation.

VIII. The period of greatest volcanic activity was prior to the main elevation of the Rocky Mountains and the depression of adjoining regions.

IX. Volcanic eruptions, elevations, and depressions of these regions stand in intimate, though inverted, connection to each other.

X. The reservoirs, forming sources for Colorado, were of comparatively shallow depth.*

* NOTE.—I may here state that I am at present preparing a more exhaustive paper on the origin of eruptives. This will discuss not only the erupted rocks of Colorado, but of the entire West.—E.

PART II.

TOPOGRAPHY.

REPORT OF A. D. WILSON, CHIEF TOPOGRAPHER.

LETTER OF TRANSMITTAL.

OFFICE OF THE UNITED STATES GEOLOGICAL AND
GEOGRAPHICAL SURVEY OF THE TERRITORIES,
Washington, D. C., January 25, 1878.

SIR: I have the honor to transmit herewith my report on the primary triangulation of Colorado; also, a description of methods of topographical, field, and office work.

The primary triangulation was in charge of Mr. James T. Gardner until the fall of 1875, when, on his resignation, the continuation of the work devolved upon me.

I completed the field-work during the summer of 1876, and have finished the computations, giving the results in the appended report.

Owing to the unfinished condition of the work when placed in my hands, and the difficulties met with in going over an immense amount of material with which I was not familiar, it is possible that some unimportant errors may occur, but I endeavored to make it as perfect as possible.

I have attempted to give a general idea of the geographical work in as concise a form as possible, designing only to convey some idea how the geographical work of the survey has been carried on, and to show upon what evidence our final maps rest.

Appended to this report I give some observations on the magnetic needle, illustrating the great range of the magnetic variation over the State. Hoping that this report may prove of interest and meet with your approval,

I am, very respectfully, your obedient servant,

A. D. WILSON,
Chief Topographer.

DR. F. V. HAYDEN,
United States Geologist in-charge.

REPORT ON THE PRIMARY TRIANGULATION OF COLORADO.

By A. D. Wilson.

CHAPTER I.

PRIMARY TRIANGULATION.

The primary triangulation party for the season of 1876 was composed, besides myself, of William H. Holmes, geologist; W. R. Atkinson and A. L. Redin, general assistants; Harry Yount and John Stewart, packers, and Spencer Butler as cook. Dr. Hayden accompanied the party for a short time himself.

The party, outfitting at Cheyenne, marched to Denver; thence by rail to El Moro, the southern terminus of the Denver and Rio Grande Railroad. Leaving El Moro on August 18, we made a station the following day on Fisher's Peak, a point just south of Trinidad. From this point we marched by way of the valley of the Purgatoire, crossed the Sangre de Cristo Range by Costilla Pass; then, skirting the west foot of the range toward the north, to the foot of Culebra Peak. On the 24th of August we ascended this point, and, having a clear day, I succeeded in taking a good set of observations on the surrounding peaks. Resuming our march the following day, we camped under Blanca Peak; but owing to a heavy rain-storm we were compelled to remain in camp until the morning of the 28th. As I had climbed this peak before, in the prosecution of my topographical work, I knew only too well what was before us; so we took as early a start as possible. Following up one of the spurs that jut out to the south we were able to ride with but little difficulty to the timber-line, where we were compelled to leave our mules. Dividing the instruments, &c., between the different members of the party, we scrambled our way up the *débris* slope, about 1,800 feet, with but little difficulty, to the first outstanding point. From this point a very narrow, saw-toothed ridge leads to the main peak, which was only about 800 feet above us, but 1½ miles away in a straight line. Taking this ridge, we scrambled along as best we could, and after two and a half hours of hard work we reached the summit of Blanca Peak. (See report of Franklin Rhoda, for 1875, for a more detailed description of this mountain and its surroundings.)

This peak is one of the finest geodetic points in all Colorado, owing to its height, position, and sharp, conical form. After spending some four hours on the top taking the numerous angles that were necessary, we began the descent, which we found less laborious, but, if possible, more dangerous than the ascent. The height of this point was determined by myself, in the following manner:

Visiting this point, as I did, first in 1875, then in 1876, it gave me an opportunity to take several barometric observations. Each time having two barometers, I compared them before starting up the mountain;

then left one at Fort Garland, to be observed every half-hour during the middle of the day, the fort being only 10½ miles in a straight line from the peak. A mean of the eight barometrical results for the difference between the peak and Fort Garland gave 6,466 feet, while, by fore and back angles of elevation and depression, the difference was 6,468.

Fort Garland was first determined by a series of readings extending over some three or four months, taken three times daily, compared with those taken at Colorado Springs by the signal service. A mean of all these results gave for Fort Garland a height of 7,997.

Later I procured the preliminary profile of the Denver and Rio Grande Railroad, which gave to the fort an elevation of 7,946 feet. Assuming this to be correct, it gives for Blanca Peak an elevation of 14,413 feet above sea-level, making it the highest point in Colorado, according to our observations. But owing to the fact that a number of points so nearly approach this figure, and to the imperfections in the barometer as an instrument for the measurement of heights in a mountainous region, where local storms and sudden atmospheric changes occur so frequently as in Colorado, it is a very difficult matter to determine with certainty which is the highest peak. Another cause for uncertainty in the absolute heights of all points in the far West is, the poor quality and the want of proper connection between the railroad levels run from the Gulf and the Atlantic seaboard by many different roads, and by many different persons. But as these levels afford the best determination which we have for the interior, we were compelled to base all our heights on them. Until some continuous line is carried through from tide-water, this uncertainty cannot be removed; consequently the absolute heights of all points in the interior must remain to some extent unsettled for the present.

From Fort Garland we marched westward across the San Luis Valley, by way of Del Norte, to the Summit district, where another station was made on Summit Peak; thence, following up the Rio Grande we made our next station on Rio Grande Pyramid, a fine pyramidal peak situated a few miles south of the river, on the continental divide.

Our next point being the highest peak in the La Plata group, we marched by way of Silverton, thence by trail down the Animas River to Animas Park and Parrott City. From the latter place we skirted the western slope of the mountains to the foot of our objective point, and on September 12 we ascended Hesperis Peak. Arriving at the summit we found the day to be one of those magnificently clear days which are only found in these high regions, and which can only be fully appreciated by one doing such work as ours, where it is so necessary to see points at such great distances. After spending some four or five hours busily taking notes, we returned to camp well pleased with the results, and on the following morning resumed our march toward the northwest, camping the first night at the Big Bend of the Dolores.

Our next point being the Abajo Peak, which was some eighty miles to the west, consequently out of our direct line of march, I determined to divide my little party, sending the main train on to await me under Lone Cone, while Mr. Holmes and myself took a small outfit and started across the mesa country for the Abajo Mountains, making a few topographical stations on the way to fill in a small area which had been left the previous year owing to the hostilities of the Ute Indians.

The second day's march brought us to the foot of the mountains, but at the same time a storm which had been accumulating for some time broke upon us, and as we were not prepared for such an event, were compelled to hover around a sage-brush fire for three days, while the

snow and rain came down alternately until the mountains were covered to a depth of a foot and a half with snow while the plains were converted into vast mud-holes. Finally, on the morning of the 19th, the storm broke and we were soon on our way up the mountain. Breaking our way through the fresh snow we succeeded in reaching the summit, where we found the snow nearly two feet deep. Completing our observations and sketches as soon as possible, nearly freezing in the mean time, we soon descended to our camp, glad to be ready once more to resume our march, for this delay had nearly entirely exhausted our supply of provisions; in fact, we had but one day's supply left and were about 100 miles from our main camp.

Late at night on the second day we reached the foot of Lone Cone, but not finding our main camp, were compelled to camp, notwithstanding the fact, which weighed heavily on our minds, that we had eaten our last morsel of provisions at five o'clock the previous morning.

Arousing ourselves at break of day the following morning and finding the weather looking unsettled, I determined to ascend the peak before spending any more time in search of camp, fearing that a storm might again delay us. After some three hours of hard climbing we reached the summit, and I succeeded in getting a good set of observations. After completing my work I scanned the horizon with my field-glasses for our main camp, which I finally discovered about seven miles eastward. Returning to where I had left the animals we soon packed up, and wending our way through down timber, bog-holes, and snow, we arrived at our camp about 4 p. m., pretty well worn and ready for a "square" meal, which we had not enjoyed for two days.

The next morning found us on our way to Uncompahgre agency, where we found some fresh supplies and mail awaiting our arrival.

From Uncompahgre agency we followed down the river nearly to its junction with the Gunnison, then turning slightly to the east crossed the Gunnison, taking an old Indian trail which we had been informed by the Indians would lead us to White River, making a station on North Mam Peak on our way; we arrived at the agency on White River September 30.

After making two stations in this vicinity, which completed our season's work, we started for Rawlin's Springs, where we arrived on the 11th of October, having occupied eleven geodetic stations, which completed the triangulation of Colorado.

From Rawlins the mules and outfit were all shipped by rail to Cheyenne, where they were quartered for the winter, and the party immediately proceeded directly to Washington.

PRIMARY TRIANGULATION.

When the survey of Colorado was commenced, in the spring of 1873, by the United States Geological and Geographical Survey of the Territories, it was found necessary to inaugurate a system of primary triangulation, in order to locate a number of points with a considerable degree of accuracy, upon which the topographical work might be based.

The first important step was to find a suitable location for the accurate measurement of a base-line. This first step is all-important, as the future work depends entirely upon the accurate measurement of the base.

After reconnoitering the country in the vicinity of Denver, Mr. Gardner selected a spot just east of the city, where a "tangent" of the Kan-

sas Pacific Railroad could be used to considerable advantage, as the greater portion of the base could be measured upon it. Mr. Gardner has kindly furnished me with the following details of the measurement:

MEASUREMENT OF THE DENVER BASE.

The base is a little over 6 miles long, and half of it is on a "tangent" of the railroad. The west end of the base is 4,811.566 feet from the end of the "tangent" and on its western prolongation.

Three and a half days were occupied in twice measuring this base. The measurement was made with a Chesterman steel tape 100 feet long, having a spring-balance attached, by which the tape was stretched, with a tension of 16 pounds. The end of each 100 feet was marked with a knife-edge on the track or on a low stool. The profile of the line was ascertained by level so that all inclined measurements might be reduced to horizontal distances. The temperature of a mercurial thermometer exposed to the sun was read every five minutes, and this was assumed to be the temperature of the tape. After two measurements of the base, the steel tape, without being used for further work, was taken to Washington and compared with the United States Coast-Survey standard for chains.

The following were the results of the two measurements of the Denver base:

First measurement.

	Feet.
Measured length corrected for temperature and slope.... .	31861.304

Second measurement.

Measured length corrected for temperature and slope......	31863.102
Total correction applied for slope..........................	—1.924
Total correction applied for temperature—	
To first measurement..................................	+2.542
To second measurement..................................	+4.67
Adopted measured length corrected for temperature and slope....................................	31862.203
Correction for error in length of tape.........................	+5.416
Correction for reduction to sea-level	—7.825
Length of base-line..	31859.794

The uncertainty of this measurement cannot probably exceed one ten-thousandth. Much of this error is doubtless due to the incorrect assumption of the relations of the temperature of the tape to that of an exposed thermometer.

From this base the work was expanded by gradually increasing triangles, with great care, to the high mountain peaks lying to the west of Denver.

The plan adopted in this work was to use the highest and more prominent peaks as stations, taking great care to select such points as would give a good system of well-conditioned triangles, and at the same time, where possible, selecting the sharper and most definite points, as they could be sighted more accurately, especially at long distances, when the monuments were not visible. Where the points were not sharp or well defined it was generally found best to sight some object, such as large rocks, or, on low points, trees, whose distance from the point where the station was afterward made could be measured. Always on occupying a point there was built a large stone monument, which could be

sighted afterward with ease at a distance of from 30 to 40 miles. In nearly all cases these monuments are the points given as the stations; in many cases the monuments were built before the point was occupied, and in such case the observations were reduced to center of the monument.

THE SAN LUIS BASE.

When the triangulation had been extended into Southwestern Colorado, a second base or base of verification was measured in the San Luis Valley and connected with the large triangles of the principal system by a smaller scheme.

The base is about $5\frac{1}{3}$ miles in length. It begins on the eastern extremity of a low gravelly ridge on the north side of Kerber Creek, near the stage-road crossing, and stretches northward diagonally across the valley.

The position was selected by James T. Gardner, and the measurement conducted by him with the assistance of Robert Adams, jr., Professor Atkinson, and Clarence Kelsey.

The total time occupied in measuring the base twice was six days, commencing August 24, 1874. Flags were placed along the line at such short intervals that three were always in sight, from which the tape could be aligned by the eye. Low stools were used for marking the distances. Their tops were of 2-inch plank and were 1 foot square. Each was supported by four iron spikes 6 inches long. Three of these stools were placed on the line 100 feet apart. The Chesterman tape was then stretched from the initial point on the first to the second stool, being pulled straight by a strain of 16 pounds, applied with a spring-balance. The 100 feet was then marked on the top of the stool with a pencil-edge. The tape was then stretched from this mark to the third stool. When this 100 feet had been marked as before, the first stool was brought forward. Each time that the tape was stretched, the bulb of a sensitive thermometer was placed against the under side of the tape and its temperature recorded. The difference of level between the stools was ascertained with a leveling-instrument and rod.

The temperature of the tape in the sun, when the breeze was light, was found to be 5° to 6° higher than that of a thermometer exposed to the sun. The results of the two measurements of the base are as follows:

First measurement.

	Feet.
Uncorrected measurement	28534.87
Corrections for slope	—10.67
Corrections for temperature	+1.40
Corrections for error of tape from United States standard at 62°	—2.86
Corrected length of base	28522.74

Second measurement.

Uncorrected measurement	28533.895
Correction for slope	—10.67
Correction for temperature	+ 2.193
Correction for error of tape from United States standard at 62°	— 2.86
Corrected length of base	28522.558
Difference of two measurements	0.18
Adopted mean	28522.65
Correction to sea-level	—10.89
Length of base	28511.76

These two measurements of this line, $5\frac{1}{3}$ miles long, differ only about 2 inches, which is a much more accurate result than that obtained at the Denver base, where the tape was laid on the railroad track and the temperature of a thermometer exposed to the sun was assumed to be the same as that of the tape. San Luis base is, of course, entitled to much more weight than the Denver base in the final adjustment of the triangulation.

AZIMUTH OF SAN LUIS BASE.

For determining the azimuth of the base, six observations were made on Polaris at the north end of the base, September 5, and four observations, September 6, at the south end of the base; six observations had been taken August 30, and ten in the evening of August 31. The mean of the observations at the south end of the base, being reduced to the north end, gave at the north end—

The azimuth of base by south-end observations......	340° 49′ 29″.32
The azimuth of base by north-end observations......	340° 49′ 24″.62

In connecting the triangulation brought down from the Denver base with the expansion from the San Luis base, it was found that there was a difference of $9\frac{1}{2}$ inches to the mile in length between the two systems, that from Denver being the greater. This difference is due, no doubt, partly to the errors in measurements of the two bases, and partly to the accumulating errors of the work as brought from Denver. In this scheme Pike's Peak enters as one of the principal points, and owing to its very flat top, it was difficult to locate with a great degree of accuracy.

The accuracy of the triangulation may be judged by the closure of triangles; the observed angles of each triangle should sum up to 180° plus the spherical excess.

The first sixteen complete triangles used in expanding from the Denver base to the high mountain-peaks, summed up with a mean error of closure of six and four-tenths seconds (6″.4), and the forty-seven triangles used in carrying the work as far south as the San Luis base and west to the Holy Cross, had a mean error of closure of ten and three-tenths seconds (10″.3).

In the whole scheme of triangulation of Colorado, there has been used in the determination of the occupied stations one hundred and forty-three complete triangles, with a mean error of closure of thirteen and three-tenths seconds (13″.3).

These errors may be considered small when we consider that natural points were used as stations, and that the angles were taken with an 8-inch theodolite, whose vernier was graduated only to ten seconds of arc and reading to five seconds.

METHOD OF ADJUSTING THE TRIANGULATION.

I present below a general description of the methods used in the adjustment of the work, omitting the minor details. In expanding the work from the measured bases, signals were established, forming as nearly equilateral triangles as possible, and the observations on these were repeated several times on different parts of the circle. The errors of closure in this way were reduced to a minimum, and this small error in the first triangles was distributed equally among the three angles. After locating some two or three points in this manner, they were then connected with the mountain stations, on which monuments had been previously built, in order that they might be more accurately sighted, in the following manner:

Having established these outside points, we then had as many different bases from which to compute the next point; so we proceeded by simply computing all the triangles we have on Mount Ouray, throwing all the errors of closure at the point sought; that is, simply using the foresights uncorrected, except for spherical excess; after calculating all the triangles in this manner, we made a plot of the intersections of these lines as calculated, say on a scale of two feet to one inch (that being the scale used in plotting those at Ouray); see Figure 1, Plate XVII.

Now, it will be seen that these lines do not meet at a given point, as they should if the work was perfect. All other things being equal, the most probable location of the point would be in the centre of gravity of the small triangles which are formed at the point by the intersections. But there are some other things which are important in determining the most probable position, such as the closure of the different triangles, the value of different sights, &c.

Taking such things into consideration as may be regarded worthy of note, we choose a point, as at Ouray, Fig. 1, where the two sights cross from Station 23 and Station 24, as the most probable position of the station on Mount Ouray, and calculate the necessary swings from Hunt's Peak and north end base to make those lines meet the other at the chosen point.

Applying these corrections to the angles at Hunt's and north base, recalculating the triangles, and we have the point Ouray located.

It will be seen that, although the triangles on Mount Ouray are fixed, we have not yet distributed the errors at the point Ouray. For instance, we have yet an error of closure in the triangle Hunt's, Station 23, Mount Ouray, of $+ 2''$; in the triangles Hunt's, Station 24, Ouray, of $+ 3''$; and in triangle Hunt's, north base, Ouray, an error of $6''$. Now, how much of this error is due to sighting Hunt's, north base, Station 23, or Station 24, is not settled. The following arbitrary method was used in distributing these errors:

First. It will be seen that if any one of these backsights become fixed, the others of necessity are fixed also, as the angles between them are already fixed by the location of the point. If we assume a series of swings, say of the sight from Ouray to Hunt's, and tabulate the result as below, we get a series of columns of swings, each one of which will satisfy the conditions of the angles at Ouray, and give a possible arrangement of the swings:

Table of swings from Mount Ouray.

	″	″	″	″	″	″	″	″	″	″	″
Hunt's	−5	−4	−3	−2	−1	−0	+1	+2	+3	+4	+5
North base	−1	−2	−3	−4	−5	−6	−5	−4	−3	−2	−1
Station 23	+7	+6	+5	+4	+3	+2	+1	+0	−1	−2	−3
Station 24	+8	+7	+6	+5	+4	+3	+2	+1	+0	−1	−2
	21	19	17	15	13	11	9	7	7a	9	11

Adding up these columns, we get the aggregate swings each would require. Other things being equal, it is best to select the column which gives the least aggregate of swings, which in this case is marked a; but there may sometimes be reasons why one point is more liable to error than the others, and in that case another column may be selected if its sum differs but little from the smaller sum; but, as a rule, it is best always to choose the column that gives the least aggregate swing. These corrections, both fore and back, should be recorded immediately in some

convenient form, as they are taken into account in all subsequent triangles in which these sides enter. In this manner the work is carried on from station to station until all are located.

The method of plotting the results as calculated from the uncorrected foresights I consider a very good check on the previous work, as any erroneous location in the previous work must appear at the new point.

Figure 4, Plate XVII, represents the foresight intersections as plotted from the preliminary calculations for the location of Mount Rito Alto. All of these sights come within a circle of about 5 feet diameter, the centre of which is assumed to be the most probable position, and the sights were accordingly swung to that point.

Figure 5 represents the condition of the foresight intersections on Summit Peak. Here we have one of the widest ranges occurring in the calculations of the work of 1876, and this is probably due to the fact that this point presents a broad top as seen from the northeast, and all of the sights from that direction are taken from a long distance; but as four out of the eight sights used meet very nearly, those triangles sum up very close to 180°, while the triangles containing the sights from Mount Rito Alto, Hunt's, Stations 24 and 28, sum up too large. I assumed the error to be mostly on those sights, and was convinced that the intersections of the sights from Blanca and South River Peaks are correct, and accordingly swung the other sights to that point.

Figure 6 represents the sights as plotted on Rio Grande Pyramid, and the small triangle, the point chosen as the station. Figure 3 shows the condition of sights on West Elk Peak.

Figure 2 gives the intersections on Mount Wilson. The peculiar position of this point makes it one of the best proofs of the accuracy of the previous work that occurs in the whole system, although it was only occupied as a secondary station. But it was sighted from every direction, and the various points from which it was sighted were located more or less by different series of triangles. The arrow-point shows from which direction the sight was taken, and the name of the point from which it was taken is placed on the other end of the line, or, in other words, nearest the station. All of these sights meet within a small area except one, and that being so much out as compared with the others, it is probable that some error was made in sighting from that station; therefore it was given no weight in the final location of the point. Many more examples might be given, but these few will be sufficient to give an idea of the character of the work, and will also serve to illustrate the general method of adjustment.

I consider the foregoing method of adjustment very simple, and, at the same time, sufficiently accurate for the class of work to which it is applied.

The primary object of this triangulation is to locate points at short intervals, upon which the topographical work could be based, and that these points should be located with such a degree of accuracy that the errors would not be appreciable within the limits of the territory on our maps, the scale being four miles to one inch, and I believe that this has been fully accomplished.

The accompanying map shows a general plot of the triangulation; all of the occupied stations are given, and a few of the located points. I did not consider it necessary to give the numerous points that have been located by foresight intersections, as it would only serve to make the plot more confusing.

The latitudes and longitudes are based on the stations located for us by the kind co-operation of the United States Coast Survey at Denver,

Fig. 1.

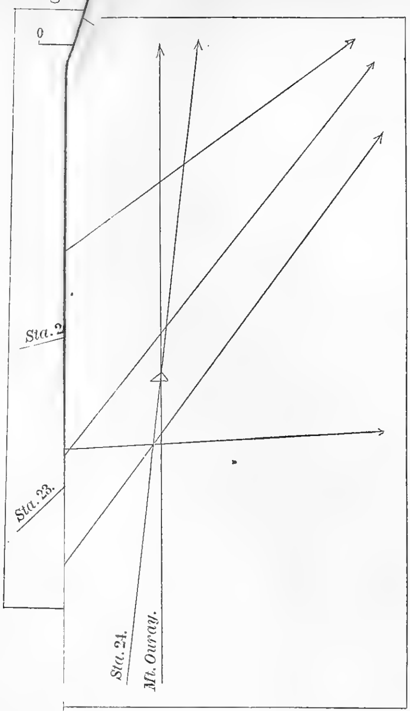

0
Sta. 2
Sta. 23.
Sta. 24.
Mt. Ouray.

Fig. 4

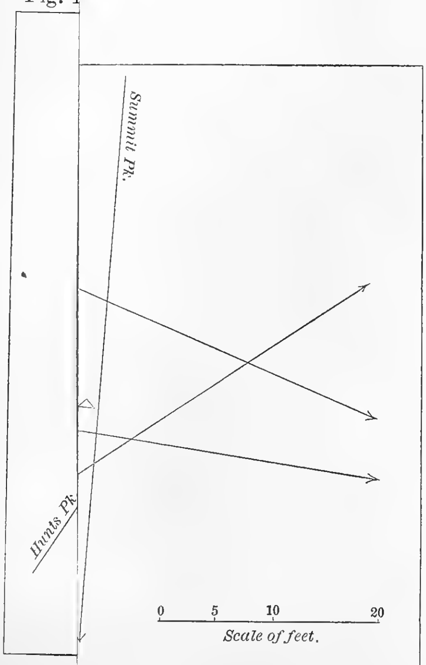

Summit Pk.
Hunts Pk
0
5
10
20
Scale of feet.

Fig. 1.

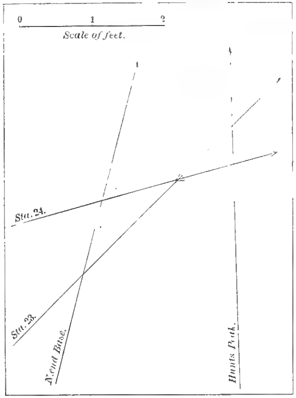


Fig. 2.

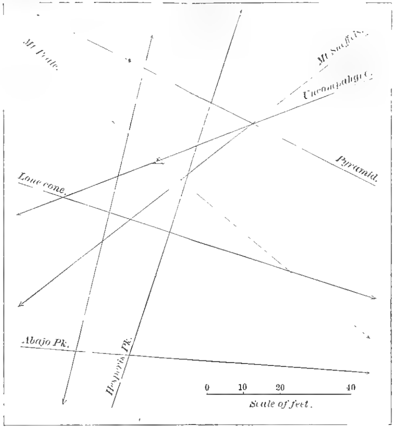


Fig. 3.

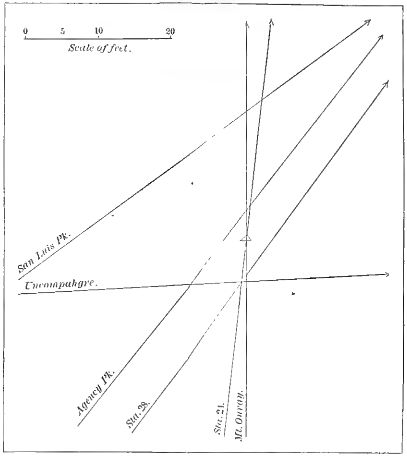


Fig. 4.

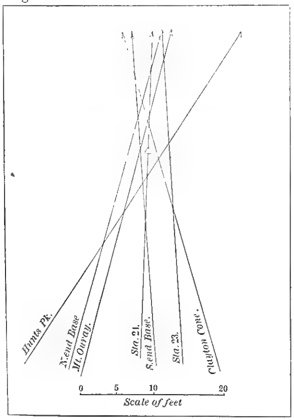


Fig. 5.

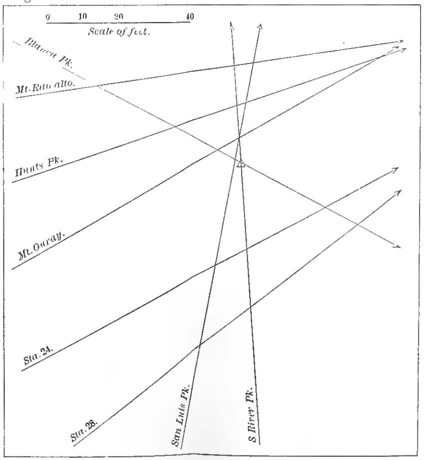
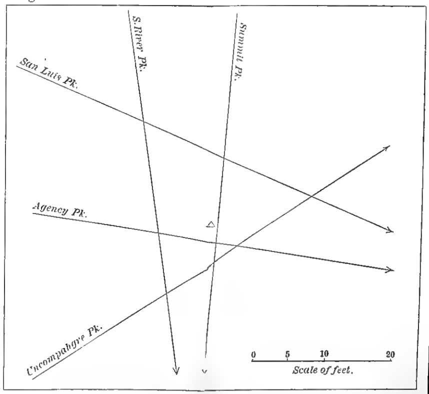


Fig. 6.



Colorado Springs, and Trinidad, and have been computed from these points.

Azimuths have been taken at intervals over the whole system.

Below will be found a list of the primary points, with their latitudes, longitudes, and elevations; also, a table of azimuths and distances from each station to the surrounding points. The azimuths are given from the south line as zero around to the right; the distances in miles and decimals thereof.

A list of the primary triangulation-stations, with their latitudes, longitudes, and elevations above sea-level.

Names of points.	Latitudes.	Longitudes.	Elevations.
	° ′ ″	° ′ ″	*Feet.*
East end of Denver base-line	39 45 52.2	104 47 39.2	5,200
West end of Denver base-line	39 46 22.7	104 54 25.3	5,200
Derrick Station	39 43 54.8	104 57 08.9	5,300
Dry Creek Station	39 56 57.0	104 55 51.8	5,500
South Boulder Peak	39 57 15.6	105 17 42.1	8,533
Mount Morrison	39 40 12.4	105 12 55.3	7,900
Long's Peak	40 15 20.8	105 36 38.2	14,271
Mount Evans	39 35 21.3	105 38 21.9	14,330
Torrey's Peak	39 38 37.4	105 48 01.1	14,336
Park View Peak	40 19 52.2	106 07 53.2	12,433
Mount Powell	39 45 41.1	106 20 10.2	13,398
Mount Lincoln	39 21 09.1	106 06 26.8	14,296
Mountain of the Holy Cross	39 28 05.2	106 23 39.1	14,176
Mount Harvard	38 55 32.2	106 19 01.3	14,375
Pike's Peak	38 50 27.3	105 02 25.6	14,147
Mount Ouray	38 25 26.1	106 13 15.7	14,043
Station 24	38 19 34.2	106 12 52.9	13,200
Station 23	38 16 34.6	106 06 00.6	12,000
Hunt's Peak	38 23 03.3	105 50 30.5	12,446
Mount Rito Alto	38 13 14.2	105 45 10.1	12,989
Station 28	37 55 18.1	106 32 16.4	12,300
Clayton Cone	38 12 58.2	105 55 29.3	9,500
Agency Peak	38 16 30.7	106 51 47.6	12,120
North end San Luis base	38 19 40.3	105 59 04.4	7,800
South end San Luis base	38 15 14.0	105 57 07.0	7,800
Blanca Peak	37 34 43.5	105 28 55.4	14,413
Culebra Peak	37 07 25.1	105 10 56.3	14,075
Fisher's Peak	37 05 59.6	104 27 31.9	9,460
Summit Peak	37 21 07.3	106 41 35.4	13,32[illegible]
South River Peak	37 34 31.7	106 58 40.2	13,160
San Luis Peak	37 59 16.8	106 55 39.2	14,100
Uncompahgre Peak	38 04 23.0	107 27 30.1	14,235
Rio Grande Pyramid	37 40 52.2	107 23 19.2	13,773
Hesperis Peak	37 26 44.2	108 05 02.2	13,135
Abajo Peak	37 50 21.7	109 27 29.7	11,000
Mount Peale	38 26 18.5	109 13 32.4	13,004
Lone Cone	37 53 19.2	108 15 04.4	12,761
West Elk Peak	38 43 09.2	107 11 44.2	12,920
Snow-mass Mountain	39 07 11.9	107 03 45.5	13,961
Leon Peak	39 04 51.0	107 50 24.7	10,954
North Mam Peak	39 23 16.6	107 51 43.8	10,973
Mount Princeton	38 45 01.3	106 14 19.2	14,199
Massive Mountain	38 39 44.7	106 28 13.6	14,368
Platte Peak	39 15 40.5	105 05 49.0	9,348
Crestone Peak	37 58 05.3	105 34 54.0	14,233
Costilla Peak	36 50 06.0	105 13 09.4	12,634
East Spanish Peak	37 23 40.5	104 54 59.9	12,720
West Spanish Peak	37 22 37.6	104 59 24.3	13,6[illegible]0
Ute Peak	37 17 02.5	108 46 24.9	9,884
San Juan Needle	36 41 15.2	108 49 50.4	....
Mount Wilson	37 50 26.4	107 59 16.9	14,280
Mount Sneffels	38 00 19.0	107 47 18.7	14,158
Pagosa Peak	37 26 43.1	107 03 47.2	12,674
Banded Peak	37 06 21.6	106 37 24.5	12,860
Station 81	37 02 30.6	106 37 31.6	12,043
Station 33	38 01 27.8	106 55 11.4	14,000
Sopris Peak	39 15 52.9	107 10 21.1	12,972
La Plata Mountain	39 01 50.3	106 28 09.2	14,311
Conejos Peak	37 17 24.5	106 34 02.4	13,183

A list of some of the more important places in Colorado, with their approximate latitudes, longitudes, and elevations above sea-level.

Names.	Latitudes.	Longitudes.	Elevations.
	° ′ ″	° ′ ″	*Feet.*
Black Hawk	39 48 00	105 29 12	7,975
Breckenridge	39 29 00	106 02 18	9,490
Boulder	40 00 42	105 16 36	5,536
Cañon City	38 26 48	105 13 51	5,260
Conejos	37 06 53	106 01 10	7,880
Caribou	39 59 48	105 34 24	9,905
Centreville	38 42 48	106 03 18	7,800
Castello's Ranch	38 57 00	105 17 12	....
Colorado Springs, United States Coast Survey Station	38 50 00.3	104 49 07.6	5,990
Denver, United States Coast Survey Station	39 45 21.8	104 59 33.5	5,240
Denver School-house	39 45 00.7	104 59 23.4	5,240
Del Norte	37 41 00	106 21 24	7,750
Dayton	39 04 48	106 22 00	9,441
Evans' Ranch, in Estes Park	40 22 30	105 29 09	7,400
Fort Garland	37 25 31	105 25 47	7,945
Fair Play	39 13 29	105 59 39	9,964
Georgetown	39 41 45	105 42 06	8,530
Greeley	40 25 24	104 41 06	4,779
Golden	39 45 30	105 12 39	5,729
Granite	39 02 00	106 00 18	8,883
Gold Hill	40 03 54	105 23 18	8,463
Hot Springs, Middle Park	40 04 48	106 05 32	7,700
Idaho	39 44 54	105 30 39	7,535
Lake City	38 01 54	107 18 42	8,550
Los Piños agency	38 11 37	106 49 36	9,290
Longmont	40 09 30	105 05 34	4,957
Malta	39 13 42	106 19 45	9,700
Middle Boulder	39 57 38	105 30 22	8,263
Nutrites Tierra Amarilla	36 42 11	106 32 52	7,480
Pueblo	38 16 36	104 33 48	4,703
Parrott City	37 20 39	108 05 00	8,611
Rosita	38 06 00	105 50 12	8,500
Saguache	38 05 43	106 08 30	7,745
Silverton	37 48 42	107 39 48	9,400
Trinidad, United States Coast Survey Station	37 10 13.8	104 30 07.5	6,100
Uncompahgre agency	38 17 15	107 47 18	6,400
White River agency	39 59 08	107 48 24	6,490

Azimuths and distances from east end of Denver base to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Pike's Peak	11 46 24	....
Platte Peak	25 06 31	38.3059
Derrick	75 05 50	8.7224
Mount Morrison	73 57 23	23.3673
West base	95 35 47	6.0341
South Boulder Peak	116 20 55	29.6720
Dry Creek Station	150 18 08	14.6702

Azimuths and distances from west end of Denver base to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Platte Peak	16 06 48	36.7356
Derrick	40 29 03	3.7274
Mount Morrison	66 44 33	17.8974
South Boulder Peak	121 21 43	24.1242
Dry Creek Station	173 59 52	12.2203
East base	275 31 31	6.0341

Azimuths and distances from Derrick to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Platte Peak	13 25 51	33.3759
Mount Evans	65 10 31	37.9258
Mount Morrison	73 09 52	14.6479
South Boulder Peak	120 12 36	23.8186
Dry Creek Station	144 19 05	15.0314
West base	180 26 57	3.7273
East base	214 59 07	8.7224

Azimuths and distances from Dry Creek Station to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Derrick	4 19 54	15.0314
Pike's Peak	4 23 03	....
Platte Peak	10 37 15	....
Mount Morrison	38 14 51	24.4825
Mount Evans	57 11 14	45.1500
South Boulder Peak	91 09 55	19.3257
Long's Peak	120 38 52	41.7524
East base	330 12 14	14.6702
West base	353 58 14	12.2203

Azimuths and distances from South Boulder Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Mount Evans	36 09 04	31.1501
Long's Peak	141 17 48	28.6823
Dry Creek Station	270 55 56	19.3260
East base	296 01 03	29.6720
West base	301 06 08	24.1242
Derrick	309 59 25	23.8186
School-house	310 50 51	21.4847
Platte Peak	347 28 40	....
Mount Morrison	347 46 55	20.0576
Pike's Peak	349 51 00	....

Azimuths and distances from Mount Morrison to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Mount Evans	76 15 46	23.2914
Torrey's Peak	86 55 37	32.1226
Long's Peak	152 40 34	45.5223
South Boulder Peak	167 49 58	20.0576
Dry Creek Station	218 03 55	24.4828
School-house	245 14 33	13.2302
West base	246 32 04	17.8976
Derrick	252 59 47	14.6479
East base	253 40 36	23.3673
Pike's Peak	350 37 01	57.9658
Platte Peak	347 18 37	28.9083

Azimuths and distances from Long's Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Mount Evans	1 54 55	46.0061
Torrey's Peak	14 36 45	43.6219
Mount Lincoln	23 08 54	67.6855
Mountain of the Holy Cross	40 34 53	71.2500
Mount Powell	48 41 28	51.4254
Park View Peak	100 52 14	28.0021
Clark's Peak	145 44 40	29.3976
Dry Creek Station	200 13 15	41.7524
South Boulder Peak	321 06 14	26.6823
Mount Morrison	332 26 11	45.5223
Pike's Peak	342 29 32	102.2415

Azimuths and distances from Park View Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Mount Powell	15 30 15	40.7758
Mountain of the Holy Cross	17 16 44	....
Snow-mass Mountain	30 59 44	97.1381
Mount Zirkel	139 53 14	45.2226
Clark's Peak	209 36 01	21.9453
Long's Peak	280 32 01	28.0021
Mount Evans	332 48 14	57.4602
Torrey's Peak	340 30 43	50.2743
Mount Lincoln	358 54 34	67.5222

Azimuths and distances from Mount Evans to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Mount Rito Alto	3 54 06	....
Hunt's Peak	11 11 13	....
Mount Ouray	21 27 58	....
Mount Princeton	29 15 59	....
Mount Harvard	38 39 16	58.4479
Mount Lincoln	57 01 13	29.8788
Mountain of the Holy Cross	79 41 28	45.5439
Torrey's Peak	111 41 33	10.1900
Park View Peak	153 07 12	57.4602
Long's Peak	181 53 49	46.0061
South Boulder Peak	215 56 27	31.1501
Dry Creek Station	236 24 39	45.1500
Derrick	254 44 34	37.9258
Mount Morrison	256 00 25	23.2914
Platte Peak	277 52 49	....
Pike's Peak	327 54 05	60.7968

Azimuths and distances from Torrey's Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Hunt's Peak	4 27 43	....
Mount Ouray	14 36 32	....
Mount Princeton	20 17 50	....
Mount Harvard	28 33 57	56.3247
Mount Lincoln	37 46 49	25.3864
Mountain of the Holy Cross	71 14 30	37.2951
Mount Powell	106 30 37	28.8329
Park View Peak	160 42 10	50.2743
Long's Peak	194 28 08	43.6219
Mount Morrison	266 32 45	32.1226
Mount Evans	291 34 04	10.1900
Pike's Peak	322 47 46	69.2939
Mount Rito Alto	357 58 10	....

Azimuths and distances from Mount Powell to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Mountain of the Holy Cross	20 28 30	21.5940
Snow-mass Mountain	41 30 56	58.8606
North Mam	72 56 57	85.4079
Park View Peak	195 21 40	40.7758
Clark's Peak	200 16 58	62.2896
Mount Zirkel	165 59 15	76.0947
Long's Peak	228 12 46	51.4254
Torrey's Peak	286 10 43	28.8329
Mount Lincoln	336 30 12	30.7364
Mount Ouray	356 27 51	....
Mount Harvard	358 57 50	57.6647

Azimuths and distances from Mountain of the Holy Cross to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Snow-mass Mountain	52 45 03	39.4744
Sopris Peak	69 40 47	39.6828
North Mam	86 11 37	74.2561
Mount Powell	200 23 05	21.5940
Long's Peak	220 00 52	71.2500
Torrey's Peak	250 49 21	37.2951
Mount Evans	259 08 54	45.5439
Mount Lincoln	291 47 55	21.3469
Mount Harvard	346 58 25	38.4013
Massive Mountain	359 02 21	19.2713

Azimuths and distances from Mount Lincoln to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Mount Ouray	5 29 41	....
Mount Princeton	9 40 55	42.1342
Mount Harvard	20 58 55	31.5288
La Plata Mountain	41 16 18	29.4930
Massive Mountain	60 02 56	22.5581
Snow-mass Mountain	72 55 44	53.6720
Mountain of the Holy Cross	112 02 01	21.3469
Mount Powell	156 38 57	30.7364
Park View Peak	178 54 49	67.5222
Long's Peak	202 49 09	67.6865
Torrey's Peak	217 35 44	25.3864
Mount Evans	236 42 42	29.8788
Pike's Peak	301 15 23	67.3390
Mount Rito Alto	346 06 51	....
Hunt's Peak	352 20 09	67.3870

Azimuths and distances from Mount Harvard to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Station 28	9 53 19	70.2684
San Luis Peak	27 18 24	72.6478
Agency Peak	33 33 31	53.7261
Uncompahgre Peak	46 48 33	85.3480
Snow-mass Mountain	108 42 45	42.2966
La Plata Mountain	131 31 52	10.9376
Massive Mountain	155 26 51	19.9659
Mountain of the Holy Cross	167 03 33	38.4013
Mount Powell	178 57 34	57.6647
Mount Lincoln	200 49 31	31.5288
Torrey's Peak	208 13 59	56.3247
Mount Evans	218 11 56	58.4479
Pike's Peak	274 25 14	69.0670
Green Horn Mountain	317 03 01	101.2664
Mount Rito Alto	327 41 11	57.4248
Hunt's Peak	331 21 36	42.4962
Mount Princeton	340 43 03	12.8056
Mount Ouray	351 26 28	34.9895

Azimuths and distances from Pike's Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Mount Rito Alto	42 15 21	57.6416
Hunt's Peak	57 24 25	58.0755
Mount Ouray	66 06 30	70.0541
Mount Princeton	84 50 12	64.9754
Mount Harvard	95 14 02	69.0670
Mount Lincoln	121 55 32	67.3390
Torrey's Peak	143 16 48	69.2939
Mount Evans	148 15 51	60.7968
Long's Peak	162 50 12	102.2415
Mount Morrison	170 43 35	57.9658
Northwest corner signal-house on Pike's Peak	306 15 21	0.0311
Fisher's Peak	345 01 19	124.2428
West Spanish Peak	358 26 36	101.0347

Azimuths and distances from Mount Ouray to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Conejos Peak	13 43 04	80.4506
Summit Peak	19 23 16	78.2971
Station 28	26 34 28	38.6946
South River Peak	35 26 57	71.6218
San Luis Peak	52 12 03	48.8060
Station 33	54 17 11	46.9518
Uncompahgre Peak	70 36 20	71.5139
Agency Peak	73 48 47	36.3576
West Elk Peak	111 24 14	56.5627
Snow-mass Mountain	136 50 11	66.1018
Mount Harvard	171 30 01	34.9895
Pike's Peak	245 21 30	70.0541
Hunt's Peak	280 08 54	15.3994
North base	297 13 31	14.4470
Mount Rito Alto	298 43 16	29.0479
West Spanish Peak	316 39 09	98.6608
Blanca Peak	325 05 44	70.8794
Station 23	327 09 50	12.1158
Station 24	357 04 55	6.7502

Azimuths and distances from Station 24 to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Conejos Peak	15 13 16	74.0074
Summit Peak	21 25 46	72.0972
Station 28	32 21 37	32.9868
South River Peak	39 04 01	66.4614
San Luis Peak	59 13 41	45.2855
Station 33	61 45 24	43.6658
Uncompahgre Peak	75 55 21	69.8995
Agency Peak	84 30 19	35.4229
West Elk Peak	117 19 30	59.6608
Snow-mass Mountain	140 20 36	71.3875
Mount Ouray	177 05 09	6.7502
Hunt's Peak	254 47 34	15.3527
Mount Rito Alto	286 01 41	26.1464
Station 23	298 54 53	7.1124
Crestone	305 25 39	42.4108
Clayton Cone	307 14 09	12.5249
West Spanish Peak	313 58 44	93.6302
Blanca Peak	321 57 37	65.2514

Azimuths and distances from Station 23 to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Station 28	44 28 02	34. 1601
San Luis Peak	66 30 00	49. 2594
Station 33	69 02 06	47. 8940
Uncompahgre Peak	79 43 45	75. 2582
Station 24	119 01 36	7. 1124
Mount Ouray	147 16 48	12. 1158
Hunt's Peak	229 06 50	11. 3806
North base	240 28 56	7. 2213
South base	280 49 35	8. 2065
Mount Rito Alto	281 25 13	19. 2785
Clayton Cone	317 58 18	5. 5831

Azimuths and distances from Clayton Cone to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Station 24	92 44 37	12. 5250
Station 23	138 02 22	5. 5831
North base	198 21 13	8. 1149
Hunt's Peak	202 49 52	12. 5760
South base	238 59 06	5. 0472
Mount Rito Alto	268 49 15	15. 1625

Azimuths and distances from north end of San Luis base to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Clayton Cone	18 19 00	8. 1149
Station 23	60 30 46	7. 2213
Mount Ouray	117 22 20	14. 4470
Hunt's Peak	210 49 57	4. 5304
Mount Rito Alto	300 20 50	14. 6108
Blanca Peak	331 52 16	....
South base	340 49 27	5. 399955

Azimuths and distances from south end of San Luis base to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Clayton Cone	58 58 06	5. 0472
Station 23	100 52 38	8. 2065
North base	160 50 40	5. 399955
Hunt's Peak	183 30 36	9. 0072
Mount Rito Alto	281 54 41	11. 0727
Blanca Peak	330 59 04	....

Azimuths and distances from Hunt's Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
South base	3 30 59	9.0072
Clayton Cone	22 49 14	12.5760
Conejos Peak	24 34 53	82.8471
Summit Peak	30 13 04	65.2836
North base	30 51 33	4.5304
Station 28	45 41 06	45.5127
Station 23	49 10 16	11.3806
San Luis Peak	63 19 12	60.2162
Station 33	65 18 23	58.7249
Station 24	74 57 44	15.3527
Mount Ouray	100 19 18	15.3994
Mount Harvard	151 35 40	42.4962
Mountain of the Holy Cross	159 02 38	....
Mount Lincoln	172 25 19	67.3870
Torrey's Peak	184 22 13	....
Pike's Peak	236 49 58	58.0755
Mount Rito Alto	317 38 35	15.2603
Blanca Peak	335 32 54	60.9589

Azimuths and distances from Mount Rito Alto to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Conejos Peak	35 02 54	78.1410
Summit Peak	40 57 28	78.9709
South River Peak	56 46 10	80.3793
Station 28	64 31 38	47.5060
San Luis Peak	76 17 59	65.9960
Station 33	78 20 56	65.0026
Uncompahgre Peak	84 16 33	93.4435
Clayton Cone	88 55 38	15.1625
Agency Peak	93 54 44	60.5112
Station 23	101 35 40	19.2785
South base	102 02 05	11.0727
Station 24	106 18 51	26.1464
Mount Ouray	119 00 41	29.0480
North base	120 29 27	14.6108
Hunt's Peak	137 45 36	15.2603
Mount Harvard	148 02 17	57.4248
Mount Lincoln	166 19 26	....
Torrey's Peak	177 59 33	....
Pike's Peak	221 48 00	57.6416
Crestone	331 47 00	19.7597
Blanca Peak	341 26 04	46.6741

Azimuths and distances from Blanca Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Conejos Peak	71 53 15	62.9059
Summit Peak	77 09 12	68.3800
South River Peak	90 17 57	82.0941
San Luis Peak	110 04 42	84.0009
Station 28	112 34 27	62.4652
Agency Peak	122 54 17	89.4401
Station 24	142 24 29	65.2514
Mount Ouray	145 33 02	70.8794
Hunt's Peak	155 49 52	60.9589
Mount Rito Alto	161 36 02	46.6741
Crestone	168 32 45	27.3952
Pike's Peak	195 16 58	....
East Spanish Peak	292 03 26	33.5634
West Spanish Peak	297 65 09	30.3923
Trinchera Peak	318 17 41	26.5818
Culebra Peak	332 10 17	35.4561
Costilla Peak	344 08 29	53.2960

Azimuths and distances from Station 28 to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Conejos Peak	2 07 47	43. 5849
Summit Peak	12 16 37	40. 1993
South River Peak	45 23 19	33. 9197
San Luis Peak	102 15 21	21. 7661
Station 33	108 53 05	22. 0217
Agency Peak	144 04 12	32. 9869
West Elk Peak	147 11 18	65. 5-97
Mount Harvard	189 45 06	70. 2684
Mount Ouray	206 22 43	38. 6946
Station 24	212 09 38	32. 9868
Station 23	224 09 22	34. 1601
Hunt's Peak	225 19 01	45. 5127
Mount Rito Alto	244 02 36	47. 5060
Crestone	266 12 27	52 3175
Blanca Peak	291 55 39	62. 4652
Culebra Peak	306 03 24	92. 5860

Azimuths and distances from Agency Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Station 33	10 06 56	17. 5663
Rio Grande Pyramid	35 09 02	50. 0120
Uncompahgre Peak	66 53 47	35. 2717
West Elk Peak	149 37 43	35. 5262
Snow-mass Mountain	169 34 54	59. 2528
Mount Harvard	213 12 47	53. 7261
Mount Princeton	225 43 04	47. 1014
Mount Ouray	253 24 35	36. 3576
Station 24	264 05 55	35. 4229
Mount Rito Alto	273 13 12	60. 5112
Blanca Peak	302 03 05	89. 4401
Station 28	323 51 52	32. 9869

Azimuths and distances from Culebra Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Costilla Peak	5 52 57	20. 0109
Station 81	86 23 13	79. 9252
Banded Peak	89 33 28	79. 5925
Conejos Peak	98 57 55	77. 2461
Summit Peak	101 09 45	84. 7721
San Luis Peak	122 25 02	112. 8426
Station 28	126 52 58	92. 5860
Station 24	146 01 48	....
Mount Ouray	147 56 26	....
Blanca Peak	152 21 12	35. 4561
Crestone	159 28 47	....
Trinchera Peak	185 48 13	11. 5657
West Spanish Peak	211 08 19	20. 4266
East Spanish Peak	218 00 08	23. 7373
Fisher's Peak	272 08 28	39. 9836

Azimuths and distances from Fisher's Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Costilla Peak	66 46 05	45. 8643
Culebra Peak	92 34 40	39. 9836
Trinchera Peak	108 58 01	40. 9069
West Spanish Peak	123 17 06	34. 9867
East Spanish Peak	128 59 40	32. 4056
Pike's Peak	165 22 08	124. 2428

Azimuths and distances from Summit Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Ute Peak	88 19 59	114.7335
Hesperis Peak	95 16 14	76.8418
Pagosa Peak	107 39 07	21.3445
Rio Grande Pyramid	120 55 27	44.4354
South River Peak	134 38 42	21.9605
Uncompahgre Peak	140 05 58	65.0359
San Luis Peak	163 44 35	45.7052
Station 28	192 10 56	40.1993
Mount Ouray	199 05 53	78.2971
Station 24	201 08 10	72.0972
Hunt's Peak	209 45 22	65.2836
Mount Rito Alto	220 22 53	78.9709
Crestone	234 46 46	74.2785
Blanca Peak	256 24 59	68.3800
Trinchera Peak	272 24 53	84.4815
Culebra Peak	280 14 54	84.7721
Costilla Peak	293 12 19	88.8762
Conejos Peak	301 34 43	8.1411
Banded Peak	347 13 01	17.3964
Station 81	350 04 25	21.7147

Azimuths and distances from South River Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Pagosa Peak	27 34 38	21.3446
Hesperis Peak	81 59 57	61.4667
Rio Grande Pyramid	108 02 45	23.6809
Uncompahgre Peak	142 41 43	43.2261
San Luis Peak	185 30 23	28.5871
Mount Ouray	214 58 59	71.6218
Station 24	218 35 52	66.4614
Station 28	224 07 10	33.9197
Mount Rito Alto	236 01 01	80.3793
Blanca Peak	269 23 14	82.0941
Summit Peak	314 28 17	21.9605

Azimuths and distances from San Luis Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
South River Peak	5 32 06	28.5871
Rio Grande Pyramid	50 07 49	32.9246
Uncompahgre Peak	101 36 20	29.5410
West Elk Peak	163 58 40	52.4865
Snow-mass Mountain	174 41 23	78.4099
Station 33	189 34 27	2.5444
Mount Harvard	206 55 30	72.6478
Mount Ouray	231 45 42	48.8060
Station 24	238 47 08	45.2855
Hunt's Peak	242 42 31	60.2162
Station 23	245 56 46	49.2594
Mount Rito Alto	255 34 22	65.9960
Crestone	270 39 49	....
Station 28	282 00 51	21.7661
Blanca Peak	289 11 29	84.0009
Culebra Peak	301 21 07	112.8426
Conejos Peak	337 34 12	52.0272
Summit Peak	343 35 55	45.7052

Azimuths and distances from Uncompahgre Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Hesperis Peak	38 33 10	55. 1859
Mount Wilson	61 09 28	33. 0635
Mount Sneffels	75 33 01	18. 6048
Mount Peale	105 13 59	99. 3589
Leon Peak	163 33 21	72. 5113
North Mam Peak	166 36 04	93. 2684
Snow-mass Mountain	196 24 06	75. 3180
West Elk Peak	197 39 52	46. 7881
Mount Harvard	226 05 56	85. 3480
Agency Peak	246 32 00	35. 2717
Mount Ouray	249 50 22	71. 5159
Station 24	255 09 12	69. 8995
Station 23	258 50 55	75. 2582
Mount Rito Alto	263 12 20	93. 4435
Station 33	276 10 59	....
San Luis Peak	281 16 50	29. 5410
Summit Peak	319 33 27	65. 0359
South River Peak	322 24 02	43. 2261
Rio Grande Pyramid	351 57 17	27. 2963

Azimuths and distances from Rio Grande Pyramid to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Mount Wilson	72 28 47	34. 6032
Mount Sneffels	135 45 05	31. 2700
Uncompahgre Peak	171 59 51	27. 2963
Agency Peak	214 49 55	50. 0120
San Luis Peak	229 50 59	32. 9246
South River Peak	287 47 43	23. 6809
Summit Peak	300 29 57	44. 4354
Pagosa Peak	312 12 00	24. 1652

Azimuths and distances from Hesperis Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
San Juan Needle	38 30 35	66. 5990
Ute Peak	73 51 09	39. 55[illegible]5
Abajo Peak	110 13 46	80. 1011
Mount Peale	138 01 15	92. 6063
Lone Cone	163 20 35	31. 8935
Mount Wilson	190 59 54	27. 7089
Mount Sneffels	202 41 51	41. 8338
Uncompahgre Peak	218 10 11	55. 1859
Mount Æolus	244 18 10	....
South River Peak	261 15 07	61. 4667
Pagosa Peak	269 41 42	....
Summit Peak	274 21 07	76. 8418
Banded Peak	285 43 31	83. 7462
Station 81	288 35 57	85. 1524

Azimuths and distances from Abajo Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Mount Peale	196 58 04	43. 2138
Lone Cove	266 40 51	66. 0793
Mount Wilson	269 30 22	80. 4208
Hesperis Peak	289 23 24	80. 1011
Ute Peak	315 19 16	53. 6508
San Juan Needle	336 16 40	86. 6281

Azimuths and distances from Mount Peale to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Abajo Peak	17 06 41	43. 2138
North Mam Peak	227 50 04	98. 3309
Leon Peak	238 55 19	86. 8808
West Elk Peak	259 21 38	111. 5550
Uncompahgre Peak	284 08 19	99. 3589
Mount Sneffels	290 28 23	....
Mount Wilson	301 04 23	79. 0586
Lone Cone	305 14 43	65. 2196
Hesperis Peak	317 19 07	92. 6063
Ute Peak	342 36 27	83. 5474

Azimuths and distances from Lone Cone to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
San Juan Needle	21 15 18	88. 7630
Ute Peak	34 40 35	50. 5908
Abajo Peak	87 25 18	66. 0793
Mount Peale	125 50 51	65. 2196
Leon Peak	194 59 46	85. 1437
West Elk Peak	224 41 22	81. 0506
Mount Sneffels	252 15 35	26. 5310
Mount Wilson	282 59 19	14. 8131
Hesperis Peak	343 14 27	31. 8935

Azimuths and distances from West Elk Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Uncompahgre Peak	17 49 39	46. 7881
Mount Sneffels	33 21 56	58. 8282
Lone Cone	45 24 51	81. 0506
Mount Peale	80 41 34	111. 5550
Leon Peak	125 52 43	42. 7650
North Mam Peak	142 21 19	58. 4113
Sopris Peak	181 55 12	37. 6256
Snow-mass Mountain	194 29 49	....
Mount Harvard	253 00 34	....
Mount Princeton	267 19 11	41. 0908
Mount Ouray	290 47 47	56. 5627
Station 24	296 42 52	59. 6608
Station 28	326 46 51	65. 5897
Agency Peak	329 25 35	35. 5262
San Luis Peak	343 48 49	52. 4865

Azimuths and distances from Snow-mass Mountain to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Uncompahgre Peak	16 38 54	75. 3180
North Mam Peak	113 33 29	46. 6935
Sopris Peak	149 48 13	11. 6533
Mount Powell	221 01 31	58. 8606
Mountain of the Holy Cross	232 20 59	39. 4744
Mount Lincoln	252 17 45	53. 6724
Mount Harvard	288 14 34	42. 2966
Mount Ouray	316 18 36	66. 1018
Station 24	319 48 44	71. 3875
Agency Peak	349 27 41	59. 2528
San Luis Peak	354 36 27	78. 4099

Azimuths and distances from Leon Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Mount Wilson	5 23 55	85.9096
Lone Cone	15 19 20	85.1437
Mount Peale	59 51 22	86.6808
North Mam Peak	176 49 29	21.2120
Sopris Peak	250 20 17	38.0282
West Elk Peak	305 28 26	42.7650
Uncompahgre Peak	243 19 04	72.5113
Mount Sneffels	357 49 30	74.2300

Azimuths and distances from North Mam Peak to—

Names.	Azimuths.	Distances.
	° ′ ″	*Miles.*
Mount Peale	48 45 43	98.3309
Mount Powell	251 57 09	85.4079
Mountain of the Holy Cross	265 17 15	74.2561
Sopris Creek	282 44 27	37.9134
Snow-mass Mountain	293 03 20	46.6940
West Elk Peak	321 56 07	58.4113
Uncompahgre Peak	346 20 55	93.2684
Leon Peak	356 48 40	21.2120

CHAPTER II.

METHODS OF TOPOGRAPHICAL FIELD AND OFFICE WORK.

The secondary triangulation was carried on by the topographers, in connection with the topographical work, with small theodolites reading to minutes of arc, and carrying powerful telescopes; the secondary triangles summed up with a mean error of closure of about two minutes. As this work was constantly checked by the primary points, the errors could not accumulate sufficiently to be perceptible on the maps.

The topographical field-work was carried on in the following manner:

First, the region of country to be surveyed was divided as nearly as possible by natural boundaries into areas sufficiently large to employ a party the whole season.

Before taking the field, the topographer supplies himself with all the information possible as to character of country, &c., and collects all the old maps that might give any idea of the existing trails, roads, or places where supplies may be obtained. Each field-party is composed of a topographer, geologist, assistant topographer, and sometimes a botanist or zoölogist accompanies them; these, with a cook, and two or three packers, complete the party. The geologist and topographer working in concert make a general plan for the summer campaign, and equip themselves with all the necessary instruments and supplies.

On reaching the district, they select the first commanding point and ascend it; on reaching the summit, the topographer sets up his theodolite, while the assistant hangs up the barometer.

The topographer proceeds to make a careful drainage sketch, on which he indicates all features of note, while the assistant makes a careful profile sketch of the entire surrounding country on a large scale. Upon these sketches are marked, by numbers or names, all the points to be sighted, or in some cases the angular readings are placed upon the sketches.

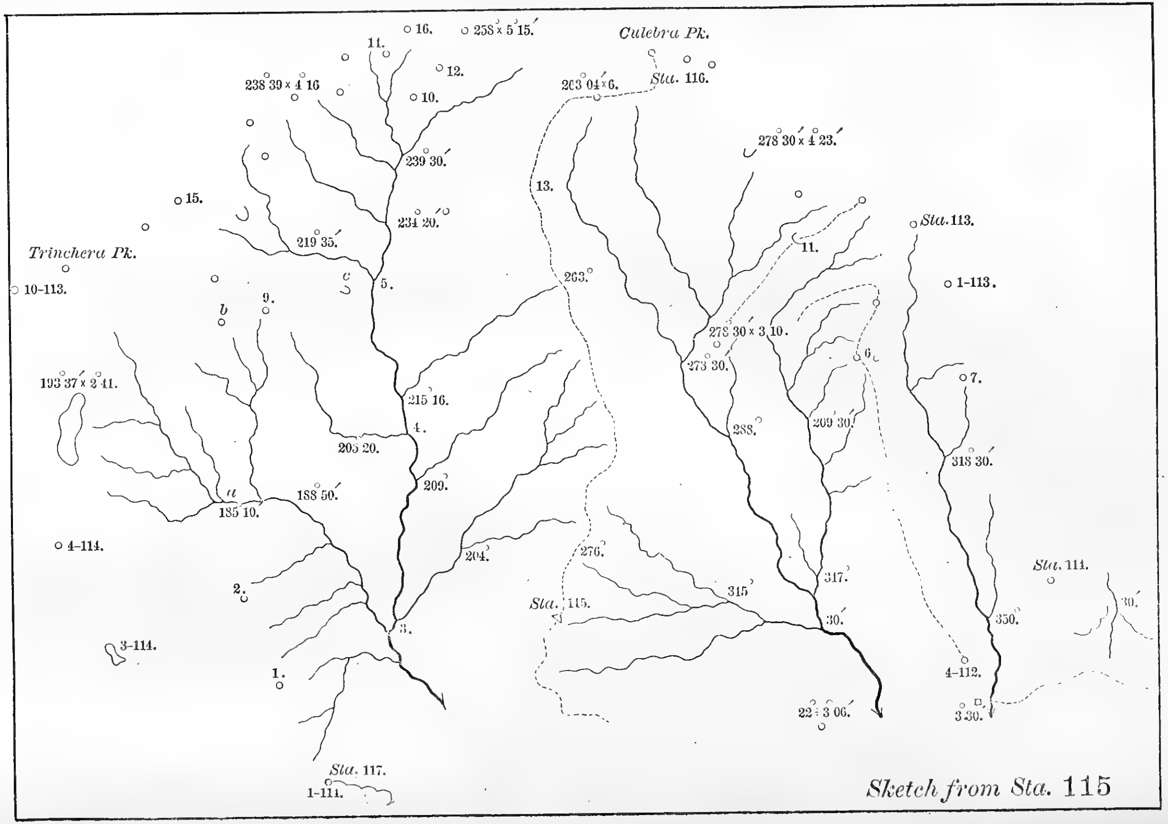
After this is done, all peaks, points, ends of spurs, junctions of streams, in fact every recognizable feature of the surrounding country are sighted, and the angles, both horizontal and vertical, recorded in a book, with their numbers or names appended.

From this first station are selected a number of points occupying commanding positions, as points to be occupied as future stations, and so on from each station there would be constantly selected points in advance, on which stations were to be made.

After finishing the work on the peak, the party proceeds to the next, and there repeats the sketches and angles, taking great care to check every previous sight possible, and taking all the new points that come within range.

Thus from day to day the country is sketched from every possible point of view, and the points are each time sighted, giving many checks to the location of all the more prominent features of the country.

The mountainous regions of the country west of the Mississippi River are generally very favorable to this kind of work. Nearly all the mount-


Culebra Pk.
Sta. 116.
Trinchera Pk.
10-113.
15.
16.
11.
12.
10.
238 39 x 4 16
239 30.
234 20.
219 35.
5.
263 04 x 6.
278 30 x 4 23.
13.
263.
Sta. 113.
1-113.
11.
278 30 x 3 10.
273 30.
288.
209 30.
7.
318 30.
9.
b
c
193 37 x 2 41.
215 16.
4.
205 20.
209.
188 50.
a
185 10.
4-114.
204.
276.
2.
315
317.
Sta. 111.
350.
Sta. 115.
30.
3.
3-114.
1.
4-112.
22 3 06.
3 30.
Sta. 117.
1-111.
Sketch from Sta. 115

ain-peaks, especially near their summits, are destitute of timber, while the valleys are uniformly so, the timber in nearly all cases growing on the slopes of the mountains.

Therefore, from the mountain-peaks the drainage of the country is clearly visible and sharply defined. Thus the topographer is often able to trace the meanderings of a stream for many miles, as it recedes over the distant plains or valleys.

To do this class of topographical work successfully, requires a man with a natural faculty for the recollection and recognition of objects which he has seen from different positions, especially in a high, rough, mountain country, where so many points are visible from one peak, and where they undergo great changes in appearance as seen from different positions.

Yet this faculty may be cultivated to a wonderful degree when the person is very careful and studies the relative positions of things, and the individual forms and characteristics of mountain structure. It is very much the same faculty that is required in recognizing faces, for each mountain has its features and individual forms. It also requires men of great physical endurance to carry on such work, owing to the many difficulties and dangers that are met with in ascending so many rough and high mountains, without any previous knowledge of the country. The traveling is often difficult through these unknown regions, where there is neither track nor trail to guide in the selection of a route, and where one is compelled by the nature of the work to reach certain points.

DETERMINATIONS OF ALTITUDES.

The altitudes have been determined with mercurial barometers. Each party is generally supplied with two barometers, and with extra tubes and fixtures with which to repair any breakage that may occur. Base barometers have been established at various points over the Territory, always as near the district in which the work was being carried on as practicable, which was often at a greater distance than was desirable, the parties often working far beyond the borders of civilization.

The heights of the mountain stations have been constantly checked by a system of vertical angles between all occupied points, thus binding the whole together, so there are but few points depending upon a single reading of the barometer for their heights, except the valleys and such places as could not be thus checked. I give below an extract from the report of Mr. Franklin Rhoda (who was my assistant during the summer of 1874), which will serve to illustrate the method of connecting the points by vertical angles:

"METHODS USED IN DETERMINING THE ELEVATION OF POINTS.

"All the elevations given in this report depend upon readings of a mercurial barometer. Where a standard barometer whose elevation is well determined is within a short distance, this instrument gives a very good determination of elevation. In the past summer, however, it was quite impossible to establish a base barometer in the vicinity of the region surveyed, without great expense. All the readings had to be referred to distant stations. Readings on high peaks were referred to the Signal-Service barometer on Pike's Peak at an elevation of 14,147 feet above the sea, while readings on all points under 12,000 feet were referred to the barometer of the United States Geological Survey at Fair Play, whose elevation is 9,964.5 feet. The first of these is 150 miles distant

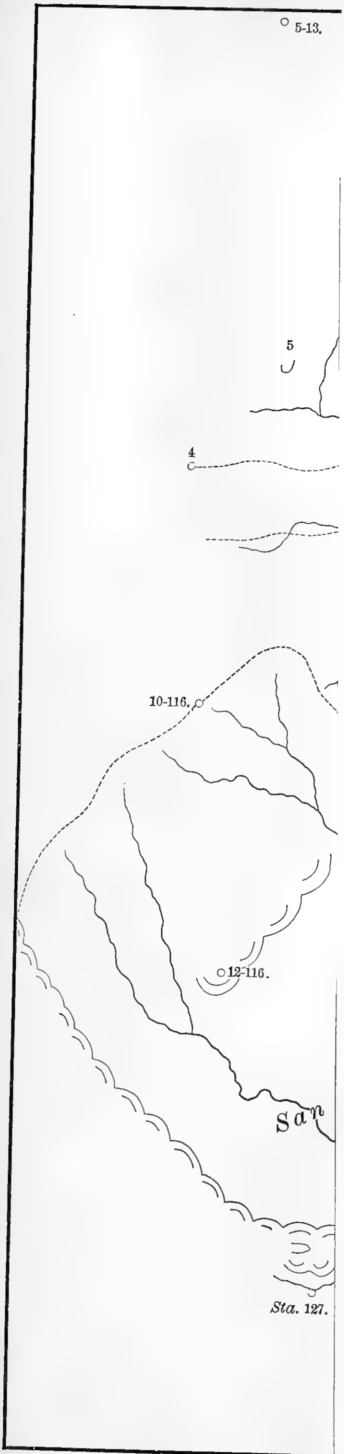
in a straight line from the central part of the San Juan country, while the second is 125 miles distant. These distances are too great to give accurate results with the barometer. At several points in the region we succeeded in getting two readings at the same point at intervals of several days, but finding that the resulting heights as calculated by reference to those distant bases did not agree well enough, it was resolved to collect together all the data possible from the field-notes and see if a fair trigonometric connection between the mountain-peaks could not be established. The result was, under the circumstances, highly satisfactory. It must be remembered, however, that the instrument used read only to minutes of arc. Supposing an error of a minute in a reading, which is not at all uncommon, the resulting error in the difference of level of two peaks from a single observation will be 15.3 feet for a distance of 10 miles and 23 feet for a distance of 15 miles. If, as is sometimes the case, the error be more than one minute, the error in the elevation will be still greater. Another large and uncertain element in the problem is refraction, which in the high mountains is so changeable as to add much to the uncertainty of the results. In many cases the observations were taken during storms, and often the peaks were sighted through breaks in the clouds, making the refraction still more uncertain. From each station angles of elevation or depression were taken to like surrounding peaks, and especially to previous stations. Had the foresight and backsights between the several stations been simultaneous, the error of the refraction correction would have been very nearly neutralized; but these two sets of observations were never taken at the same time, and in only one case on the same day. From each of two stations I always succeeded in finding some peaks which had been sighted from both. With this material on hand, the distances were obtained from Mr. Wilson's plot of his secondary triangulation, which will not probably involve, in any case used, a greater error than five-hundredths of a mile, which includes the error due to shrinkage of paper, as these distances were all hastily taken off from the map with a scale. Having, then, the horizontal distance between the two stations, and the angle of elevation or depression from one to the other, of course the difference of level can be determined. But on account of the errors which have crept into these angles from the cause above mentioned, one determination of the difference of level is not sufficient. For a still finer approximation, wherever vertical angles had been taken from two stations to the same point, the height of that above and below each station was calculated. From this another determination of the difference in the height of the two stations was determined; then the height of another unvisited point was calculated, and so on for all the near points sighted from both stations. Each point gives one determination of the difference of the two stations. In some cases it will be found that one result is far out from the rest. This may be due to the fact that sights to the different points which have received by mistake the same number in the notes have been used. Such cases are thrown out and a mean of the rest assumed as the true difference of level. It was found that on account of errors of refraction and imperfections of the instrument, sights over 15 miles in length could not be depended on at all. In the following calculation no sights of that length were used, and in fact very few over 10 miles have been used. In making the calculation, the following formula was used, taken from Lee's tables:

$$dh = 0.00000485\,K\,A \pm 0.000000667\,K^2;$$

in which dh is the difference of level of the two points, K the horizontal distance in yards, and A the number of seconds in the vertical

angle used. In this formula are contained corrections for both curvature and refraction, the latter element being assumed equal to 0.078 of the curvature. On examining the notes carefully it was found that there were sights to many hundreds of different peaks, and it became a difficult problem to utilize all this material and at the same time do it according to a system. After a number of experiments on different methods it was found that to bring order out of this chaos it was necessary to take up each link in the chain separately, and use all the data that could be found pertaining to it, and determine the difference of level of these two stations finally. Next the same process had to be gone through with the line from the second point to the next station beyond, and so on. In doing this, it was found that some of these lines were much better determined than the others. In finally reducing these differences of level to a common datum point, this fact might multiply the errors in the work. For instance, a number of well-determined differences of level might be transferred through a poorly-determined line, thus vitiating all with the error of the one. In order to obviate this the following scheme was adopted: A central chain of well-determined lines was carried through the heart of the mountain mass, from Mount Wilson, the most westerly of the high peaks, to Station 8, five miles east of Uncompahgre Peak, in the northeast corner of the mass. From this main line several secondary branches were carried wherever the short lines could be well determined. This system covered the whole mass of mountains. Other stations, which could not be well enough determined independently, were connected with different points in the main lines. In the central line we have the following parts: From Mount Wilson to Station 30, a peak east of it and distant 9.3 miles, is a fall of 383 feet, which is the mean of five determinations having a range of 32 feet; thence east to Sultan Mountain, a distance of 6.88 miles, with a fall of 536 feet, the mean of six determinations, range 23 feet; thence northeast to Station 16, distant 6.60 miles, a rise of 175 feet, the mean of nine determinations, range 35 feet; thence northeast to Handie's Peak, 7.51 miles, a rise of 456 feet, the mean of eight determinations, range 54 feet; thence north to Uncompahgre Peak, distant 11.14 miles, a rise of 238 feet, the mean of nine determinations, range 49 feet; thence east to Station 8, distant 4.92 miles, a fall of 1,380 feet, the mean of ten determinations, range 67 feet. This completes the central or trunk line, whose length is 46.35 miles. From Sultan Mountain a branch was extended eastward from this peak to Station 25, distant 10.28 miles, a rise of 209 feet, the mean of twelve determinations, range 67; thence to Rio Grande Pyramid, distant 8.63 miles, a rise of 197 feet, the mean of nineteen determinations, range 95. From Station 25, a branch extends to Mount Oso, distant 7.29 miles, a rise of 64 feet, the mean of seven determinations, range 37. From Station 30, a secondary branch was extended south and west. Station 30 to Engineer Mountain, distant 6.98 miles, a fall of 926 feet, the mean of eight determinations, range 22; thence west to Station 36, distant 6.76 miles, a fall of 417 feet, the mean of eleven determinations, range 51; thence to Station 37, distant 3.65 miles, a rise of 94 feet, the mean of five determinations, range 35. Another important subline extends from Sultan Mountain to the northwest. The first link in the chain is the line from this point to Station 28. The heights of Stations 30 and 16 above Sultan Mountain having been already well determined from the central chain, I made use of all the connections between Station 28 and each of these points, reducing all of them to a common point. The result from this was the following: Sultan Mountain to Station 28, distant

7.86 miles, a fall of 484 feet, the mean of eighteen determinations, range 76 feet; thence to Station 9, distant 3.77 miles, a rise of 324 feet, the mean of eight determinations, range 43 feet; thence to Mount Sneffels, distant 5.94 miles, a rise of 952 feet, the mean of six determinations, range 36 feet; thence to Station 34, distant 6.65 miles, a fall of 1,161 feet, the mean of five determinations, range 23 feet. This completes all the well-determined chains. Other stations on which barometric readings have been taken were connected with as many points in the main lines as possible, and these being reduced to a common point, a mean was taken. Such points are the following: Sultan Mountain to station 10, a fall of 223 feet, the mean of eleven determinations, range 76 feet; Uncompahgre Peak to Station 5, a fall of 1,498 feet, the mean of ten determinations, range 85 feet; Uncompahgre Peak to Station 11, a fall of 3,624 feet, the mean of eight determinations, range 111 feet; Sultan Mountain to Station 51, a fall of 835 feet, the mean of three determinations, range 75 feet; Sultan Mountain to Station 48, a fall of 1,061 feet, the mean of six determinations, range 59 feet; Handie's Peak to station 13, a fall of 1,175 feet, mean of fore and back sights, range 6 feet. Besides these, there are two which depend on single determinations. First, from Sultan Mountain to the point in Baker's Park where the road crosses Cement Creek in Silverton, distant 3 miles, a fall of 3,961 feet; second, from Mount Sneffels to Station 32, which is obtained from sights to a common point between them, distant from Mount Sneffels 2.04 miles, and from Station 32, 3.75 miles, the fall is 5,050 feet. This difference of level is checked by sights to distant points to the south of Station 32. These two cases are admitted because the distances were so short as to preclude the possibility of any considerable error. From these results a table was made out showing the heights of each station, above or below a common datum point. Sultan Mountain was selected as the datum point from its central location, and also from the fact that it was situated on the great central chain of levels, at its junction with two principal sublines. A second column was added, giving the height of each station as determined by the single barometric reading taken thereon. A third column was made out of the first two, by adding the number in the first column to the one in the second when preceded by the minus sign, and by subtracting it when plus. This column represents the elevations above sea-level of Sultan Mountain as determined from the barometric readings at the several stations. It will be seen that the twenty-three results have a range of 203 feet. A mean of all these was assumed as the true height of Sultan Mountain; and by reversing the previous process and adding the plus differences of height in the first column and subtracting the minus, a fourth column was obtained, giving the elevation of each station as reduced from the mean of the twenty-three readings. A fifth column was added, giving the date of each reading on the different stations. From this it will be seen that the observations extend from August 1 to October 6—more than two months. By examining the table carefully it will be seen that nearly all the earlier readings give heights above the mean and the latter below it. Whether this is merely accidental, or due to some physical law, I cannot tell. It will be seen that several of these stations, whose height relative to the rest has been well determined, do not appear in the table. This is due to the fact that at those stations, either from storms or other causes, we failed to get barometric readings.


5-13.
5
4
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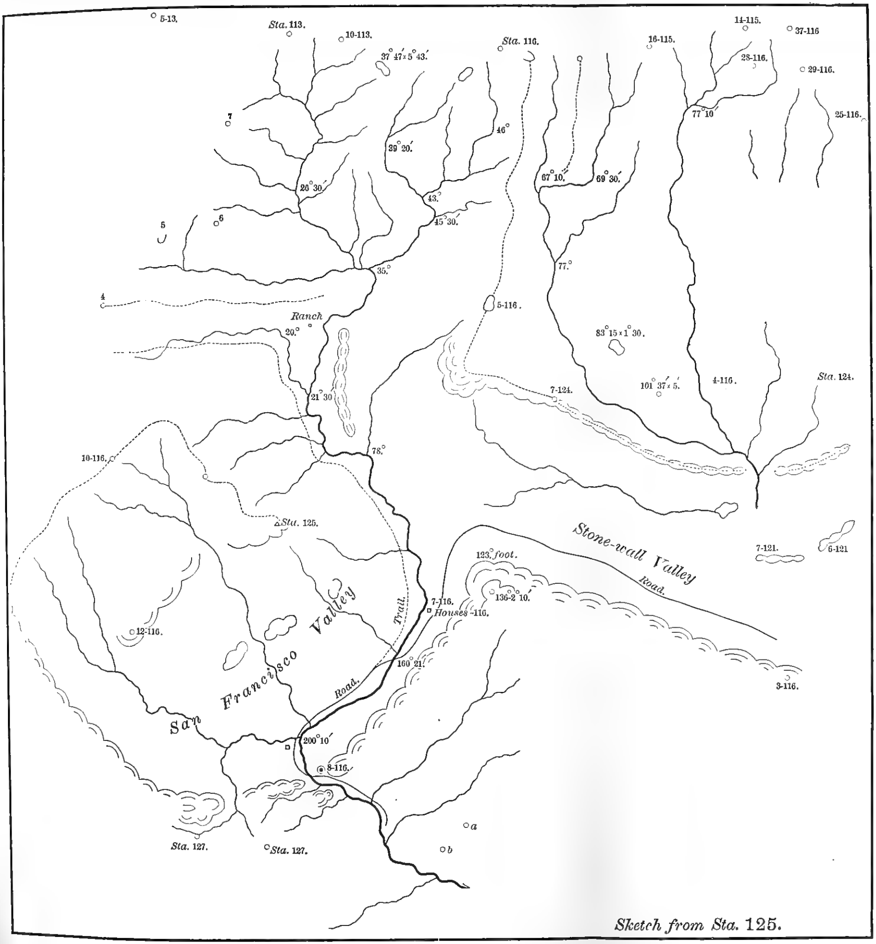
San
Sta. 127.



Sketch from Sta. 125.

"Name of station.		Height above or below Sultan Mountain.	Absolute height of station from barometric reading.	Resulting height of Sultan Mountain.	Final height of station.	Date of barometric reading.
"Station 5	—	629	12, 770	13, 399	12, 737	Aug. 1, 1874.
"Station 8	—	511	12, 960	13, 471	12, 855	Aug. 6, 1874.
"Uncompahgre Peak	+	869	14, 337	13, 468	14, 235	Aug. 8, 1874.
"Station 10	—	223	13, 082	13, 305	13, 143	Aug. 10, 1874.
"Station 11	—	2, 755	10, 684	13, 439	10, 611	Aug. 12, 1874.
"Station 13	—	544	12, 895	13, 439	12, 822	Aug. 14, 1874
"Handie's Peak	+	631	14, 101	13, 470	13, 997	Aug. 15, 1874.
"Station 16	+	175	15, 593	13, 418	13, 541	Aug. 17, 1874.
"Rio Grande Pyramid	+	407	13, 801	13, 394	13, 773	Aug. 22, 1874
"Sultan Mountain		....	13, 298	13, 298	13, 366	Aug. 31, 1874
"Silverton	—	3, 961	9, 377	13, 338	9, 405	Aug. 31, 1874.
"Station 27	—	777	12, 491	13, 268	12, 589	Sept. 3, 1874
"Station 29	—	160	13, 120	13, 280	13, 206	Sept. 4, 1874
"Station 30	+	531	13, 927	13, 396	13, 897	Sept. 6, 1874
"Station 32	—	4, 258	9, 027	13, 285	9, 108	Sept. 9, 1874.
"Mount Sneffels	+	792	14, 162	13, 370	14, 158	Sept. 10, 1874
"Station 34	—	369	12, 988	13, 357	12, 997	Sept. 11, 1874
"Mount Wilson	+	914	14, 185	13, 271	14, 280	Sept. 13, 1874.
"Station 36	—	812	12, 538	13, 350	12, 554	Sept. 14, 1874
"Station 37	—	718	12, 623	13, 341	12, 648	Sept. 15, 1874.
"Station 38	—	320	13, 014	13, 334	13, 046	Sept. 20, 1874
"Station 48	—	1, 061	12, 321	13, 382	12, 305	Sept. 30, 1874
"Station 51	—	835	12, 518	13, 353	12, 531	Oct. 6, 1874
"Mean		....	....	13, 366		

"With the elevations of these stations determined, the heights of unvisited points were obtained by applying the difference of level as obtained from the vertical angle to the height of the station from which the angle was taken. As most of the unvisited points are sighted from many stations, we have for each a number of determinations, of which the mean is taken. Many of these points are quite as well determined as some of the stations."

OFFICE-WORK OF THE TOPOGRAPHER.

On the return of the parties to the office, each of the topographers calculates and constructs a projection on a scale of two miles to one inch, on heavy mounted drawing-paper. On each sheet are plotted, by latitudes and longitudes, all the primary points that had been located in the district, with a sufficient number of secondary points from which to plot the remainder of the stations, with large eight-inch circular protractors reading to minutes of arc.

After locating all the stations, they establish all the points that have been sighted from the numerous stations, upon the sheet. When all the points are placed upon the sheet in the foregoing manner, the drainage is located by plotting first all points along the streams that have been sighted, such as junctions, noted bends, &c., then all the minor details from the drainage-sketches are filled in, carefully studying all the different sketches that contain the streams in question.

The sketches are made on a scale from three to four times larger than that at which the final maps are plotted; so there is generally more detail on the sketches than can be represented on the maps. Plates XVII and XVIII represent these sketches, which are actual tracings from the field-book, with the notes, &c., as taken from Stations 115 and 125 by myself.

Turning to the sketch, it will be seen that every junction and important bend is sighted, and that all the prominent peaks are indicated in their relative positions, as nearly as could be judged. Comparing this with the map as plotted (see Plate XXI), we find that it is somewhat distorted, as might be expected when we consider that the sketch was made entirely by eye. But at the same time it will be seen, after all the points are actually located, that the remainder of the drainage can be sketched in very correctly.

Now we have the frame-work of the map upon the paper; it is inked in and we are ready to commence the drawing of the hill-structure, which we indicate by contour-lines, each representing 200 feet of vertical distance. By these lines we give the approximate heights as well as forms of the mountains as nearly as we know them, from the numerous height and profile sketches which we have taken from every occupied station. I will state here that I do not attempt in this paper to give all the minor details of this work, proposing only to give a general idea of the methods used in constructing the maps. First, all the heights are calculated and tabulated in some convenient form for reference.

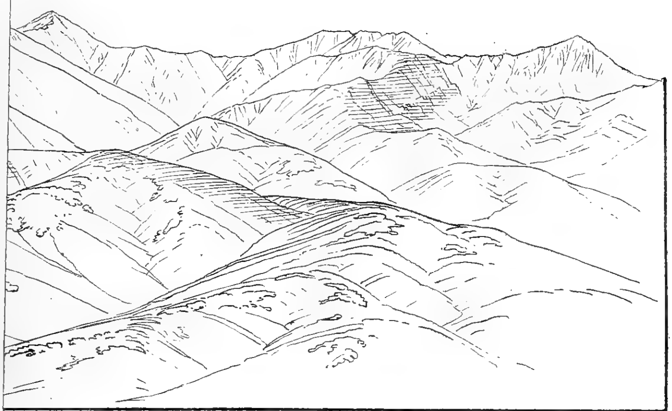
Having our points and drainage located, we start, for instance, with the heights of the points (*a*) and (*b*) (see Plate XX); the difference between these two points we find to be about 3,000 feet; the contours being 200 feet apart, we have fifteen to be distributed between these two points; they are accordingly spaced in from the sketch nearer together or farther apart as the slope is greater or less. Next we find the point marked (9) to be about the same height as (*b*), and the point on the stream marked (5) to be nearly the same as (*a*); consequently we have fifteen contours to space in between these points. But we find from the height of (*c*) that five of these come between points (*c* and 5), therefore coming much nearer to each other, as the slope is greater than between (*c* and 9), where they are nearly equidistant from each other, as the slope is comparatively even and gentle.

Now we turn to the sketch from Culebra Peak, which will give us the profile of the ridge from (9) to (*d*), and in the same manner space in the contours. We can now connect these lines, carefully studying the sketch, to see how deep the ravines are cut, and the general forms of the ridge which lead from (9) to the valleys below. In this manner all of the mountains are carefully drawn as we have sketches such as are given from Stations 115 and 125 from every point that has been occupied, with the heights of all located points, besides many more that do not appear as located points, such as valleys, passes, benches, &c. Plates XVIII, XIX, and XX will give some idea of the field-sketches, while Plate XXI will show the map as finished in the office, only at a much reduced scale. This plate is taken from a proof of the engraved sheet to illustrate the result of this method of work.

To give some idea of the amount of work that has been done by the topographical corps in the survey of Colorado, I will state that we have established 1,280 topographical stations within an area of about 70,000 square miles, and from each station all the surrounding country was sketched as previously described. My assistant made over one thousand pages of profile sketches during the field-season of 1875, each page being 6 by 10 inches, while I myself made some five hundred pages of drainage-sketches, and took the thousands of angles that were necessary to locate all the points.

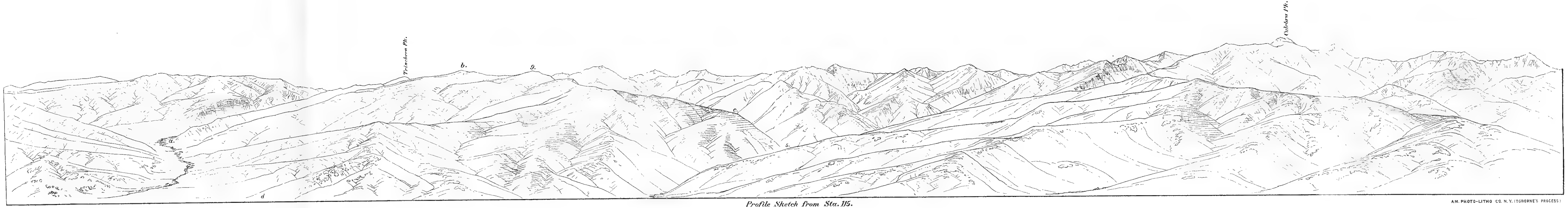
In referring to the sketches given, the system of numbering the points may not be clearly understood. Turn to Plate XIX, for instance,

Plate XX.



AM. PHOTO-LITHO CO. N. Y. (OSBORNE'S PROCESS)

Plate XX.



Profile Sketch from Sta. 115.

AM. PHOTO-LITHO CO. N.Y. (OSBORNE'S PROCESS)

you will see there such numbers as (16–115), (14–115), (29–116), &c., which mean simply No. 16 from Station 115, No. 14 from Station 115, and No. 29 from Station 116. These numbers are obtained in the following manner: Beginning at Station 1, we sight, say, one hundred points; it will be seen at once that there must be some short and efficient method adopted by which these points can be designated when sighting them from the stations that are to follow. To give each a descriptive name becomes impossible, owing to the number and the time it would take, which is a very important consideration to the topographer, for his time is so much taken up by the ascent and descent of the mountain that he is compelled to economize time in every possible manner. Each point is numbered, commencing with one; these numbers are placed on the sketches over or by the point to be sighted, and when the angles are taken and recorded, the number of the point is placed after its angle. From the next station as you sight the points, place the same number after the angle, but instead of the simple numbers write (1–1), (2–1), (3–1), which signify, as before stated, point 1 from Station 1, point 2 from Station 1, &c.; and this designation or name, as it may be called, is always used thereafter, except where they are afterward occupied as stations; it is then more convenient to substitute the number of the station in place of the old one.

Any new points sighted from Station 2 are numbered again, commencing with one as before, and these become (1–2), (2–2), (3–2), and so on from station to station as above, (16–115), (14–115), the first number always referring to the number from the given station, while the second gives the number of the station.

This system of numbering was originally developed by myself, and I have used it for several years in connection with this class of topographical work, and find it as short and at the same time as complete a system of giving names to the many points that are necessary to sight as any that I have seen. It also facilitates the plotting very much. For instance, in plotting you come to a point in the notes of Station 125 marked 14–115; you know at once by turning to Station 115 that you will find another reading on this point 14, and that you will probably find it sighted from the intermediate stations. Thus much time is saved in looking for the necessary checks to any point that you may wish to locate.

Sometimes the bearings are simply placed on the sketches, especially of points that are not likely to be sighted often, such as minor points, stream junctions, &c.; in that case the horizontal angle is first recorded; then follows the vertical angle, with a plus or minus sign placed before it to show whether it be an angle of elevation or depression, thus: $83^\circ 15' + 1^\circ 30'$.

Over the more settled portions of the country, the principal roads have been meandered with compass and odometer.

The final results of the work in Colorado will be published in the form of an atlas, containing six topographical sheets drawn in contours as above described. These sheets were originally drawn on a scale of two miles to one inch, then reduced to a scale of four miles to one inch, and engraved on stone. The projection is so constructed that the six sheets may be mounted as one map. The six corresponding geological sheets are printed in colors on the contour sheets as bases.

The general drainage map was compiled mainly from the final sheets and is published at a scale of twelve miles to one inch. This map was designed for general distribution, and gives, as well as the drainage system, all of the roads, trails, railroads, towns, prominent mountain-

peaks, with their heights, &c. Upon this map as a base are printed the general geologic and economic maps of the whole State of Colorado.

The economic map has been constructed from notes taken by the members of the different parties while in pursuit of their regular duties. Upon this sheet are given as nearly as possible the outlines of the agricultural, grazing, timber, mineral, and desert lands, each represented by different colors.

The atlas also contains two sheets of geological sections, and two of characteristic panoramic views. These, with the primary triangulation map, completes the atlas.

DECLINATION OF THE MAGNETIC NEEDLE.

I give below a table of declinations of the magnetic needle, with the approximate latitudes and longitudes of the points of observation. It will be seen at a glance that little dependence can be placed on the compass over the greater part of this region, especially in the mountain portions, where the variation has a range from 5° to 24°, and this occurs in a small area.

In the plains and mesa country of the southwestern part of Colorado the declination is much more regular, ranging from 13° to 15°. The declination all along the southern part of Colorado and northern portion of New Mexico is about 13° 30′, where it is not disturbed by local attractions. This gradually increases as you go north until it reaches 15° 30′ at the northern border of the State.

It will be seen from the table that it is difficult to give any definite declination for even a small area of country, as the local attraction varies greatly within a small area.

This wide range of the magnetic variation has no doubt been a very fruitful source of error in all of the older explorations through the interior, when in their meandering systems so much dependence had to be placed on the compass, and, having no fixed points to correct these errors by, they must have accumulated to considerable proportions over every considerable area of country or every extended line, even though they were often checked by azimuth observations.

Point of observation.	Latitude.		Longitude.		Date.	Declination east.	
	°	′	°	′	1873.	°	′
Station 1	38	29	106	06	July	14	40
Mount Ouray	38	25	106	13	....do	12	26
North of Ouray	38	30	106	15	....do	12	10
Station 4	38	27	105	56	....do	14	30
Station 5	38	28	105	51	....do	11	00
Station 7	38	20	105	42	....do	16	40
Station 8	38	17	105	33	....do	16	23
Station 10	38	31	105	22	....do	14	30
Station 11	38	27	105	16	....do	9	30
Station 13	38	14	105	18	....do	22	40
Station 15	38	11	105	26	....do	15	35
Station 16	37	54	105	33	....do	15	27
Station 19	38	08	105	43	....do	15	01
Mount Rito Alto	38	13	105	45	....do	15	38
Hunt's Peak	38	23	105	50	....do	14	10
Station 23	38	17	106	06	....do	12	06
Station 24	38	20	106	13	August	19	47
Station 28	37	55	106	32	....do	13	25
Station 33	38	01	106	55	....do	17	40
Agency Peak	38	16	106	52	....do	14	23
Station 35	38	24	106	42	....do	15	10
Station 37	38	29	106	31	....do	13	30
Station 38	38	41	106	37	....do	14	40
Station 42	38	49	106	39	....do	14	40
Station 44	38	42	106	27	....do	15	50
Station 45	38	35	106	22	....do	14	00

Plate XXI.

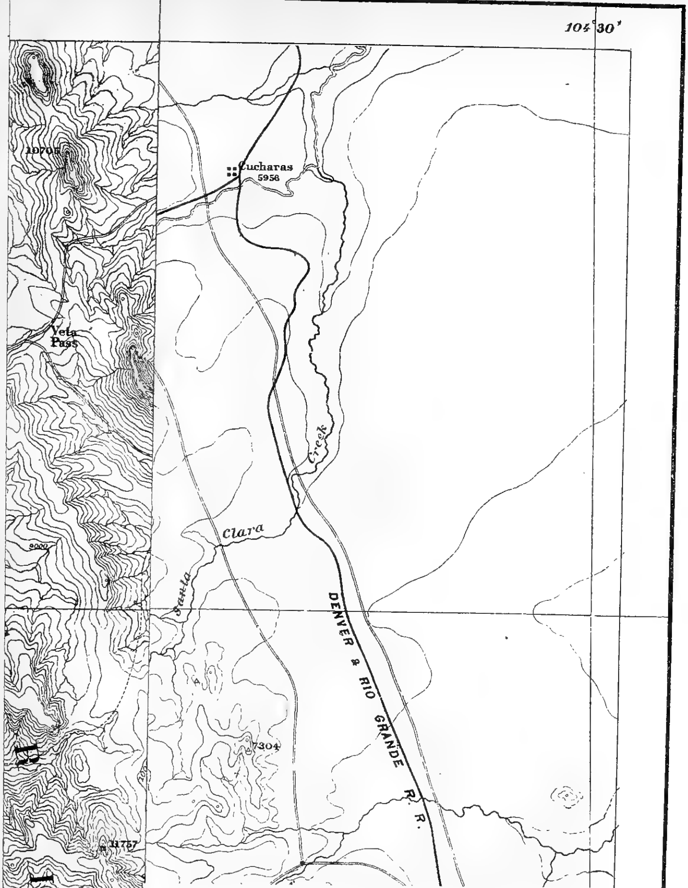
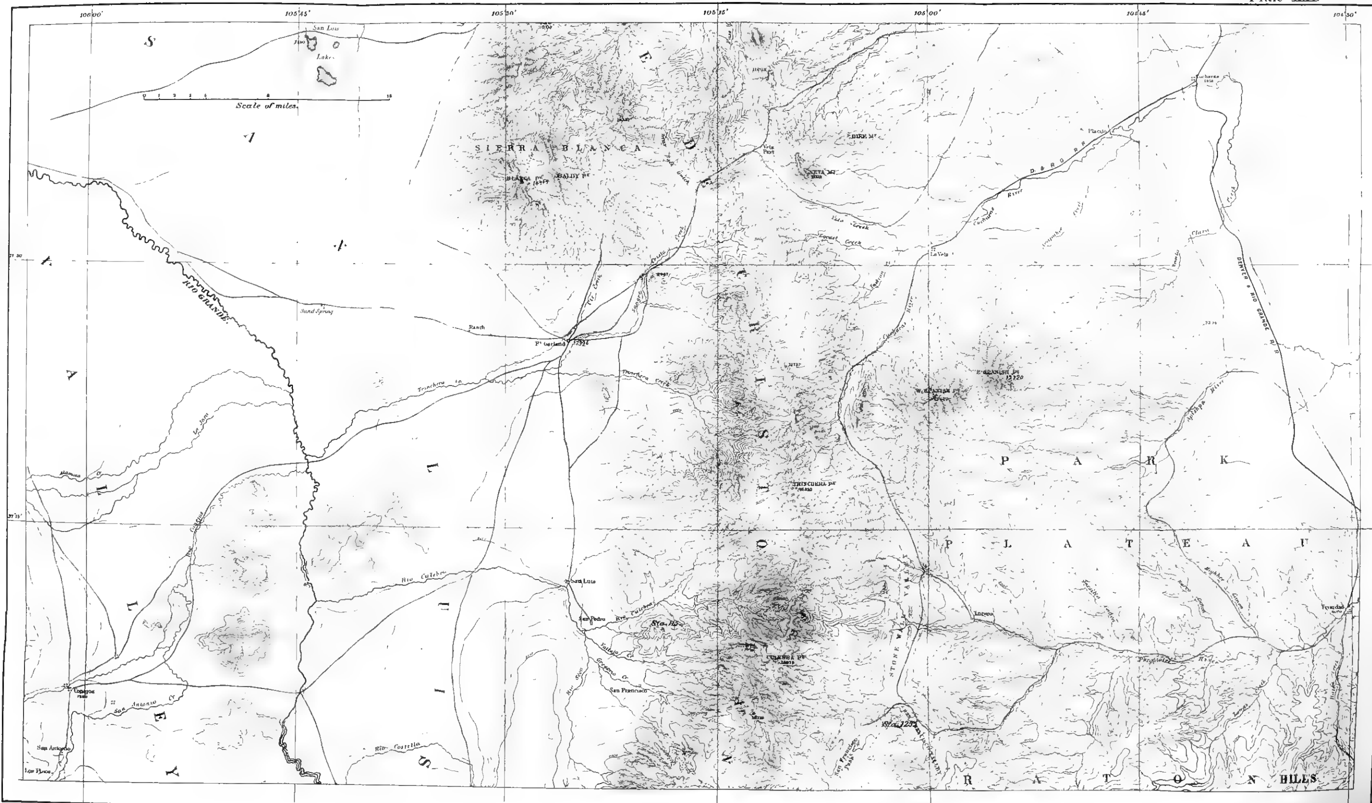

104°30'
10705
Cucharas
5956
Veta Pass
Creek
Clara
Santa
DENVER & RIO GRANDE R. R.
7304
11757

Plate XXI.


106°00'
105°45'
105°30'
105°15'
105°00'
104°45'
104°30'
37°30'
37°15'
Scale of miles.
San Luis Lakes
S A N L U I S V A L L E Y
S A N G R E D E C R I S T O
SIERRA BLANCA
BLANCA Pk
BALDY Pk
DIKE Mt
VETA Mt
Veta Pass
Veta Creek
Locust Creek
La Veta
Cucharas River
D. & R. G. R.R.
DENVER & RIO GRANDE R.R.
RIO GRANDE
Sand Spring
Ranch
Ft Garland
Trinchera Cr.
Trinchera Creek
Sangre de Cristo Creek
E. SPANISH Pk 12720
W. SPANISH Pk
TRINCHERA Pk
Apishpa River
P A R K
P L A T E A U
Alamosa Cr.
Conejos
San Antonio Cr.
San Antonio
Los Pinos
Rio Culebra
San Luis
San Pedro
Vallejo Cr.
San Francisco
Rio Costilla
CULEBRA Pk
STONE WALL
Purgatoire River
Trinidad
R A T O N HILLS

Point of observation.	Latitude.		Longitude.		Date.	Declination east.	
	°	′	°	′	1873.	°	′
Mount Princeton	38	45	106	14	August	15	40
Station 50	38	38	106	13	....do	16	10
Station 52	38	47	106	02	September	13	30
Station 54	38	41	105	57	....do	14	47
Black Mountain	38	43	105	41	....do	15	00
South of Black Mountain	38	36	105	41	....do	12	10
Station 61	38	29	105	46	....do	18	50
Station 63	38	28	105	38	....do	14	44
Station 65	38	31	105	28	....do	15	20
Station 67	38	34	105	33	....do	12	40
Station 71	38	43	105	33	....do	14	05
Station 73	38	31	105	16	....do	14	40
Station 80	38	01	105	01	....do	16	35
Station 81	37	53	105	00	....do	14	00
Mount Pisgah	38	46	105	13	....do	13	55
Station 90	38	41	105	10	....do	14	08
Station 91	38	38	105	07	....do	15	00
Station 92	38	39	105	00	October	14	15
Station 98	39	48	104	49	....do	15	00
Pike's Peak	38	50	105	02	....do	14	24
Mount Harvard	38	56	106	19	....do	15	41
La Plata Peak	39	02	106	28	....do	14	04
Grizzly Peak	39	03	106	36	....do	17	38
Italia Mountain	38	57	106	45	....do	16	05
Snow-mass Mountain	39	07	107	04	....do	13	18
Station 69	39	00	107	03	....do	23	40
Crested Butte	38	53	106	56	....do	22	10
Park Cone	38	48	106	36	....do	14	52
Station 75	38	50	106	24	....do	11	20
Station 76	39	05	106	42	....do	15	00
Sopris Peak	39	16	107	10	....do	15	12
Holy Cross	39	28	106	29	....do	17	17
Station 89	38	47	106	14	....do	14	15
Castle Peak	39	01	106	51	....do	13	08
					1874.		
Station 2	37	58	107	04	July	15	28
Station 3	38	08	107	12	....do	14	50
Station 8	38	03	107	22	August	6	00
Station 10	37	59	107	36	....do	13	12
Station 11	38	02	107	18	....do	15	15
Station 19	37	48	107	19	....do	13	45
Rio Grande Pyramid	37	41	107	23	....do	12	56
Station 27	37	52	107	42	September	14	30
Station 29	37	57	107	42	....do	14	34
Station 30	37	48	107	50	....do	9	00
Engineer Mountain	37	42	107	48	....do	13	56
Station 32	37	57	107	52	....do	16	00
Station 34	38	02	107	54	....do	16	55
Mount Wilson	37	50	107	59	....do	13	08
Station 36	37	43	107	56	....do	16	15
Station 37	37	41	107	59	....do	14	23
Station 42	37	26	107	55	....do	14	00
Station 44	37	17	107	49	....do	14	20
Station 47	37	20	107	42	....do	14	26
Station 50, valley	37	24	107	32	October	13	25
Station 56	37	49	106	55	....do	14	06
Station 57	37	40	106	36	....do	14	40
Del Norte	37	40	106	21	....do	13	36
Station 64	37	51	105	54	....do	13	37
Station 59	37	37	106	09	....do	15	40
Station 1	40	22	105	46	August	15	50
Station 7	40	22	106	16	....do	15	00
Station 21	40	21	106	56	....do	13	56
Station 25	40	25	107	13	....do	15	30
Station 27	40	23	107	22	September	15	40
Station 28	39	57	107	48	....do	16	07
Station 29	39	57	107	53	....do	15	55
Station 31	40	08	107	42	....do	15	50
Marvin's Peak	39	54	107	12	....do	18	50
Station 47	39	53	107	05	October	15	40
Station 77	39	59	106	39	....do	15	30
Homestake Peak	39	22	106	25	....do	12	45
Station 5	39	38	106	30	....do	14	40
Station 6	39	39	106	40	....do	15	50
Station 9	39	35	106	54	....do	14	48
Station 11	39	30	107	01	....do	15	37
Station 18	38	33	107	27	....do	17	00
Station 16	38	31	107	22	....do	12	30
Station 22	38	33	107	35	....do	19	45
Station 23	38	25	107	35	....do	16	55

Point of observation.	Latitude.		Longitude.		Date.	Declination east.	
	°	′	°	′	1874.	°	′
Station 24	38	20	107	30	October	14	15
Ohio Peak	38	48	107	03	....do	18	16
Mount Owen	38	55	107	07	....do	17	00
Land's End	38	46	107	32	....do	20	30
Station 40	38	52	107	45	....do	16	30
Station 42	39	01	107	46	....do	14	25
Lion Peak	39	05	107	50	....do	16	05
North Mam Peak	39	23	107	52	....do	26	08
North Mesa	39	06	108	14	....do	20	00
Station 73	38	29	107	17	....do	15	15
Station 79	38	36	107	31	....do	17	00
					1875.		
Station 1	38	04	104	44	June	9	16
Station 3	37	54	104	44	....do	14	11
Veta Mountains	37	35	105	09	....do	13	53
Grayback Mountains	37	40	105	22	....do	13	30
Near Garland	37	29	105	20	....do	15	35
Blanca Peak	37	35	105	29	....do	15	00
Near Fort Garland	37	25	105	25	....do	14	00
Near Del Norte	37	49	106	24	....do	14	48
Northwest Del Norte	37	45	106	35	....do	12	48
Station 13	37	44	106	22	....do	13	26
Pintada Peak	37	29	106	21	....do	13	20
Summit District	37	27	106	36	....do	15	17
Summit Peak	37	21	106	42	....do	11	09
Station 21	37	27	106	48	July	15	20
Station 24	37	40	106	38	....do	13	44
Near Wagon Wheel Gap	37	47	106	48	....do	17	11
South River Peak	37	35	106	59	....do	16	38
Station 30	37	36	107	03	....do	14	18
Station 31	37	41	107	07	....do	16	05
Antelope Park	37	46	107	05	....do	17	20
Station 34	37	48	107	06	....do	15	34
Station 35	37	38	107	16	....do	17	00
Station 36	37	33	107	14	....do	13	50
Station 37	37	30	107	11	....do	14	05
Pagosa Peak	37	27	107	04	....do	14	00
Station 40	37	23	107	09	....do	14	50
Station 42	37	13	107	09	....do	13	53
Station 46	37	17	107	26	....do	13	53
Station 47	37	15	107	35	....do	14	18
Station 50	37	12	107	44	....do	13	51
Mouth of Florida	37	03	107	52	....do	13	40
Station 52	36	57	107	52	....do	14	30
Station 53	36	52	107	59	....do	13	58
Station 55	36	42	108	02	....do	14	16
Station 57	36	43	107	52	....do	15	00
Near mouth of Los Pinos	36	49	107	40	....do	16	08
Station 60	36	45	106	55	....do	14	10
Station 61	36	46	106	43	August	16	30
Station 62	36	52	106	46	....do	13	53
Station 63	36	58	106	44	....do	14	50
Station 64	36	59	106	58	....do	10	30
Starion 65	37	02	106	58	....do	13	27
Station 66	36	57	107	07	....do	13	30
Station 67	37	02	107	23	....do	13	40
Station 68	37	04	107	26	....do	13	44
Station 70	36	48	107	40	....do	13	33
Station 71	37	01	107	12	....do	13	17
Station 73	37	04	107	05	....do	13	28
Station 74	37	09	107	01	....do	13	40
Station 75	37	10	107	00	....do	14	10
Station 76	37	20	106	56	....do	14	40
Blackhead Peak	37	17	106	46	....do	13	57
Station 79	37	09	106	52	....do	13	51
Station 80	37	04	106	51	....do	14	08
Station 82	36	55	106	36	....do	13	44
Station 85	37	09	106	37	....do	15	41
Conejos Peak	37	17	106	34	....do	19	01
Station 87	37	12	106	35	....do	13	50
Station 91	37	03	106	19	....do	24	37
Station 92	36	55	106	21	....do	14	05
Brazos Peak	36	49	106	23	....do	13	38
Station 94	36	45	106	25	....do	13	26
Station 95	36	50	106	17	....do	13	38
San Antonio Mountain	36	52	106	01	....do	13	02
Prospect Peak	37	05	106	10	September	10	38
Chiquita Peak	37	21	106	14	....do	14	32
Station 102	37	17	105	48	....do	19	37
Station 105	37	12	105	44	....do	5	00

Point of observation.	Latitude.		Longitude.		Date.	Declination east.	
	°	′	°	′	1875.	°	′
Ute Peak	36	57	105	41	September	11	09
Ute Peak, east side	36	57	105	40	....do	13	58
Venado Peak	36	47	105	30	....do	13	11
San Luis Valley	36	50	105	36	....do	13	46
Station 110	36	53	105	20	....do	13	34
Costilla Peak	36	50	105	13	....do	15	18
Boundary Peak	37	00	105	17	....do	13	39
Station 114	37	04	105	20	....do	13	31
Station 115	37	09	105	19	....do	14	02
Culebra Peak	37	07	105	11	....do	12	56
Station 117	37	13	105	21	....do	14	07
Station 120	37	24	105	10	....do	15	22
West of Spanish Peak	37	23	104	59	....do	14	23
West Spanish Peak	37	23	104	59	....do	11	03
Trinchera Peak	37	17	105	10	....do	13	54
Station 123	37	16	105	02	....do	14	10
Station 125	37	05	105	02	....do	14	15
Station 126	36	59	105	03	....do	14	00
Station 127	37	02	104	59	....do	14	00
Station 129	37	09	104	45	October	14	00
Fisher's Peak	37	06	104	28	....do	23	47
South of Fisher's	37	03	104	27	....do	13	00
Station 133	37	15	104	31	....do	12	48
Station 136	37	15	104	44	....do	24	13
Station 138	37	27	104	41	....do	13	56
Station 142	37	47	105	09	....do	18	57
Station 11	36	43	108	04	July	13	44
Station 14	36	46	108	24	....do	14	10
Station 15	36	56	108	23	....do	13	30
Station 16	36	57	108	20	....do	13	30
Station 17	37	47	108	32	....do	13	54
Station 18	36	51	108	32	....do	13	30
Station 20	36	51	108	43	....do	14	10
Station 21	36	48	108	41	....do	14	02
Station 23	36	58	108	55	....do	14	05
Station 27	37	05	108	30	....do	14	10
Station 30	37	16	108	14	....do	14	20
Station 35	37	17	108	28	....do	13	55
Station 36	37	21	108	45	....do	14	14
Ute Peak	37	17	108	46	....do	16	40
Station 39	37	26	108	50	....do	13	52
Station 40	37	24	108	56	August	14	20
Station 41	37	26	109	04	....do	14	14
Station 42	37	13	109	10	....do	14	30
Station 43	37	12	109	18	....do	14	30
Station 44	37	29	109	20	....do	15	50
Station 45	37	19	109	26	....do	14	10
Station 46	37	10	109	24	....do	14	15
Station 47	37	10	109	02	....do	14	30
Station 52	36	48	109	10	....do	15	00
Station 54	36	54	109	22	....do	14	30
Station 55	36	58	109	11	....do	13	05
Station 56	37	01	108	59	....do	13	50
Station 20	38	11	108	13	1875.	10	00
Station 30	38	38	108	29	....do	16	00
Station 31	38	40	108	36	....do	14	45
Station 40	38	48	108	37	....do	6	30
Station 63	38	28	109	00	....do	16	00
Station 67	38	30	109	11	....do	16	15
Station 68	38	27	109	14	....do	16	00
Station	38	11	108	41	1876.	14	00
Station	38	06	108	47	....do	13	30
Station	38	06	108	52	....do	11	00
Station	38	01	108	42	....do	14	40
Station	37	57	108	24	....do	15	30
Station	39	01	109	10	....do	15	00
Station	38	54	109	15	....do	16	00
Station	38	46	109	22	....do	15	00
Station	39	01	109	19	....do	16	20
Station	39	11	109	38	....do	13	30
Station	39	15	109	33	....do	14	15
Station	39	19	109	32	....do	15	00
Station	39	22	109	26	....do	14	45
Station	39	25	109	10	....do	16	30
Station	39	38	108	55	....do	14	00
Station	39	36	108	48	....do	14	40
Station	39	24	108	35	....do	15	55

REPORT OF HENRY GANNETT, M. E.

LETTER OF TRANSMITTAL.

WASHINGTON, D. C., *February* 4, 1878.

SIR: I have the honor to transmit to you herewith a short report on the arable and pasture lands of Colorado. This report embodies not only the result of my own observations, but those of all other members of the survey who have assisted in the geological and geographical work in this State. From several other gentlemen, citizens of Colorado, I have received valuable data. Among them I would especially mention Mr. E. S. Nettleton, C. E., of Pueblo; Capt. E. L. Berthoud, C. E., Golden City; William N. Byers, of the Denver News, and Mr. N. C. Meeker, of the Greeley Tribune.

Owing to the fact that the area which I surveyed during the field-season of 1876 was in detached portions, and was supplementary to the work of 1875, I made but one report on the work of those two years. This report appeared in the annual report of the survey for 1875.

I am, very respectfully, yours,

HENRY GANNETT.

Dr. F. V. HAYDEN,
United States Geologist.

REPORT ON THE ARABLE AND PASTURE LANDS OF COLORADO.

BY HENRY GANNETT, M. E

CHAPTER I.

PHYSICAL GEOGRAPHY.

TOPOGRAPHY.

The area of Colorado is 104,500 square miles. Of this, nearly all of the eastern half, or about 45,500 square miles, consists of plains; the middle portion, comprising about 32,000 square miles, is mountain country, more or less rugged, containing several large valleys, most of which are at a considerable elevation; while the western portion, or 17,000 square miles, consists of plateau country.

The mean height of the State above the sea is 7,000 feet, being the highest of the States or Territories. The lowest part of the State is at its eastern boundary, where it is little above 3,000 feet, while the highest mountain-summits reach altitudes above 14,000 feet.

The areas between the different thousand-foot contour-lines are given in the following table:

	Square miles.
Between 3,000 and 4,000 feet	9,000
Between 4,000 and 5,000 feet	21,800
Between 5,000 and 6,000 feet	15,000
Between 6,000 and 7,000 feet	10,000
Between 7,000 and 8,000 feet	11,000
Between 8,000 and 9,000 feet	14,000
Between 9,000 and 10,000 feet	10,000
Between 10,000 and 11,000 feet	6,800
Between 11,000 and 12,000 feet	5,000
Between 12,000 and 13,000 feet	1,400
Above 13,000 feet	500

The general slope of the plains is toward the eastward. At the base of the mountains they are from 5,000 to 7,500 feet above the sea, while at the eastern boundary of the State the elevation is 3,000 to 4,000 feet. Their surface is rolling or undulating, with broad, flat valleys and low divides.

The plains are drained by the South Platte, Republican, and Arkansas Rivers with their branches. The first and last have their sources in the mountains in many streams, which unite in the plains. The other stream rises and has its course entirely in the plains.

From the foot of the mountains, in latitude 39°, an elevated swell in the plains in the form of a flat, broad ridge, runs eastward, separating the drainage of the Arkansas from that of the South Platte. This, known as "The Divide," or "The Arkansas Divide," is about 7,500 feet in elevation, but decreases in height eastward. Northward, the plains at the foot of the mountains slope gently down to a mean elevation of between 5,000 and 6,000 feet. Southward the slope is more rapid, reaching a height of 5,000 feet at the debouchure of the Arkansas from the mountains; thence the general level rises again, and keeps a mean elevation not far from 5,500 feet to the southern boundary of the State.

With the exception of a few groups of eruptive mountains, the whole mountain area is made up of a succession of parallel ranges and valleys,

having the normal Rocky Mountain trend, that is, 20° or 30° east of south and west of north. The courses of the streams belong to one of three systems: 1st. Those flowing nearly east or west. These are, in all cases, the larger streams, and their courses, utterly disregarding, as they do, the trend of the ranges, indicate that they preceded the uplift of the latter, and their directions show the prevailing slopes of the land in those earlier times. Rivers live longer than mountains. The courses of this class of streams, known as "antecedent drainage," being in most cases transverse to the ridges and valleys, we find them alternately and for short distances only, in open valley and in close cañon. Of this class are the two forks of the Platte, the Arkansas, the San Juan, the Gunnison, Grand, White, Yampa, and perhaps the Rio Grande. The *extreme heads* of these streams belong plainly, however, to the second class. This comprises all streams whose courses are parallel to the ranges and are direct results of their uplift. The class includes most second-rate streams, nearly all of which have courses parallel to the ranges. Their courses are in valleys of more or less width, seldom in cañon. This class is known as "consequent drainage."

The third class, the "superimposed drainage," comprises all streams flowing down the slopes of the ranges, with courses, generally speaking, at right angles to their trend.

In this State these three classes of water-courses are very strongly marked, and do not merge into one another, except in the case of antecedent streams heading in consequent streams, which is, of course, to be expected. An antecedent stream does not, in any case, become a consequent stream farther down its course. The greater part by far of the agricultural land in the mountain area of Colorado is in the valleys of consequent streams.

Rising quite abruptly from the western border of the plains is a succession of mountain ranges placed *en echelon*, so as to present an almost unbroken front to the plains from the northern to the southern boundary of the State. The northernmost of these ranges extends from near Long's Peak northward into Wyoming. It is known as the Laramie Range, or the Black Hills of Wyoming. South of this is the Colorado or Front Range, which overlooks the plains from Long's Peak southward to the debouchure of the Arkansas from the mountains, and farther southward the front rank of the Rocky Mountains is formed by the Sangre de Cristo Range, with, for a short distance, the Wet or Greenhorn Mountains as a skirmish-line. West of this chain of ranges lies a succession (from north to south) of high, broad mountain valleys, separated from one another by groups of eruptive mountains or mases of hills. These valleys are known as the North, Middle, South, and San Luis Parks. West of these valleys is another succession of ranges. The most northern of these, the Park Range, forms the western wall of the three northernmost of the parks; and, west of North and Middle Parks, it is the last range, the country to the westward consisting of a succession of broken plateaus, gradually lessening in elevation as we trace them westward.

West of South Park and the Park Range lies the consequent valley of the Upper Arkansas, and around the southern end of this range, through the broken hills which succeed it, the river finds its way to the plains. Beyond the Valley of the Upper Arkansas rises the Sawatch Range, and this is succeeded by the parallel ranges and irregular masses of the Elk Mountains.

The San Luis Valley is limited on the west by the great mass of the San Juan Mountains, an immense, rugged nucleus, from which radiate in all directions heavy, long spurs, many of which are of sufficient importance to merit the name of ranges.

West of this and the Elk Mountains a broken expanse of desert plateaus, arid and waterless, stretches toward the setting sun farther than the eye can reach.

The total width of the mountain district in the latitude of Middle Park is 75 miles; in the latitude of South Park, to the western extremity of the Elk Mountains, is 150 miles; and farther south, across San Luis Valley and the San Juan Mountains, it is even broader, being about 180 miles.

CLIMATE.

The climate of Colorado is characterized by great dryness of the atmosphere, slight rain-fall, and that in sudden, short, showers, during which it seems as if the heavens were opened; extremes in temperature, very low in winter and high in summer, hot in the day and cool at night, and subject to very sudden and great changes. The direct heat of the sun's rays is very great. Very high winds and "dust-storms" are of frequent occurrence. The prevailing winds are from the northwest and west.

The rain-fall is of so variable and explosive a character, that it can be depended on for little, except to do damage. The following table, made up from Smithsonian Contributions and the reports of the Signal Bureau, although very meagre, will give an idea of the amount of the natural watering which this State receives:

Table of monthly and annual rain-fall.

	Fort Massachusetts.	Fort Garland.	Fort Lyon.	Fort Morgan.	Montgomery.	Mountain City.	Golden City.	Denver.	Colorado Springs.	Cheyenne, Wyo.
Latitude	37° 32′	37° 32′	38° 08′	40° 15′	39°	39° 35′	39° 45′	39° 45′	38° 53′	41° 12′
Longitude	105° 23′	105° 40′	102° 50′	103° 46′	106°	105° 40′	105° 20′	105° 04′	104° 58′	104° 42′
Height, feet	8, 365	7, 945	3, 725	4, 506	10, 783	....	5, 729	5, 244	6, 032	6, 075
January	0. 34	0. 11	0. 32	0. 31	4. 55	....	....	0. 39	0. 15	0. 05
February	0. 86	0. 21	0. 12	....	1. 00	0. 25	....	0. 29	0. 37	0. 06
March	0. 61	0. 33	0. 16	....	3. 70	0. 97	....	0. 84	0. 57	0. 55
April	1. 25	0. 34	2. 09	0. 00	5. 56	0. 60	....	1. 78	2. 03	0. 59
May	1. 19	0. 33	4. 84	2. 55	11. 73	....	5. 40	3. 92	4. 87	2. 14
June	0. 71	0. 77	1. 40	0. 73	....	....	3. 50	1. 52	1. 04	1. 07
July	2. 01	1. 29	2. 53	0. 52	....	....	3. 94	3. 22	3. 44	2. 48
August	2. 84	1. 27	0. 37	0. 60	....	....	0. 50	1. 35	1. 10	1. 54
September	1. 80	0. 76	0. 04	0. 00	....	....	2. 20	1. 71	1. 87	0. 88
October	0. 87	0. 33	0. 00	0. 19	....	4. 00	....	0. 54	0. 13	0. 54
November	3. 61	0. 24	0. 07	....	....	3. 20	....	0. 71	1. 19	0. 35
December	1. 07	0. 13	0. 15	....	2. 10	....	....	0. 47	0. 29	0. 05
Spring	2. 95	1. 00	7. 09	....	20. 99	....	....	6. 54	7. 87	3. 28
Summer	5. 56	3. 33	4. 30	1. 85	....	....	7. 94	6. 19	5. 58	5. 09
Autumn	6. 28	1. 32	0. 11	....	....	....	....	2. 96	3. 19	1. 77
Winter	2. 27	0. 45	0. 59	....	....	....	....	1. 15	0. 81	0. 16
Year	17. 06	6. 11	12. 09	......	....	....	....	16. 84	17. 15	10. 30

Of these, Forts Lyon and Morgan are well out in the plains, far from the immediate influence of the mountains. Cheyenne, Denver, and Colorado Springs and Golden City are near the edge of the plains, just at the foot of the mountains. Forts Massachusetts and Garland were located (the former has long been abandoned) on the eastern side of the San Luis Valley but a few miles apart. The former was nearer the mountains, and at a greater elevation than the latter. The very marked increase in rain-fall, owing to the slightly different topographical situation, will be noted. Montgomery and Mountain City are in high mountain valleys, closely hemmed in by high, rugged ranges.

As was stated above, nearly all of this rain-fall is in the form of sudden showers, of short duration, and of small extent. Owing mainly to this last feature, the annual rain-fall will be found to differ very materially even between points but a few miles apart. This is especially the case among the mountains, where all the climatic conditions are modified very much by local topography.

Proceeding westward over the plains, the rain-fall is seen to decrease in amount and become more variable in character. Entering the mountains, the precipitation is noticed to increase in quantity, still, however, preserving its character. The winter precipitation is husbanded in the form of snow, which, in the late spring and early summer, melts and, swelling the streams, is utilized for irrigation. The mountains thus play, in a measure, the part of reservoirs.

Farther west, on the lower plateaus, the rain-fall is reduced to a minimum, and the country presents all the aspects of a desert.

Table of monthly and annual mean temperatures.

	Cheyenne, Wyo.	Denver.	Colorado Springs.	Fort Lyon.	Fort Morgan.	Fort Reynolds.	Fort Sedgwick.	Cañon City.	Fair Play.
Latitude	....	39° 45′	38° 50′	38° 08′	40° 15′	38° 15′	40° 58′	38° 28′	39° 13′
Longitude	....	105° 00′	104° 49′	102° 50′	103° 46′	104° 12′	102° 23′	105° 15′	106°
Elevation, feet	6,100	5,250	6,032	3,725	4,500	4,300	3,600	5,400	9,964
January	23.8	26.57	28.2	26.01	19.78	32.26	26.23	24.2	20.0
February	30.7	32.75	34.9	35.65	33.67	36.23	31.60	34.6	21.8
March	26.8	31.85	33.5	39.68	30.52	41.67	34.65	36.4	19.5
April	42.4	46.90	46.5	49.72	47.20	51.73	46.25	45.5	33.3
May	50.6	60.28	54.9	64.74	58.25	63.13	59.49	....	44.0
June	60.8	67.13	64.0	74.80	71.00	72.50	70.88	....	57.4
July	64.0	72.68	64.6	79.65	78.99	78.79	78.81	....	57.0
August	63.2	67.70	65.3	76.13	79.85	73.94	72.21	....	56.0
September	56.0	61.26	57.9	64.33	70.65	64.38	60.62	....	49.1
October	47.9	48.78	51.3	49.08	57.41	50.98	49.62	....	....
November	30.3	39.22	37.1	39.08	....	39.78	40.20	....	....
December	33.4	22.45	35.4	27.37	29.31	27.06	28.51	36.6	25.1
Year	44.1	48.13	47.8	52.02	....	52.70	49.92	....	....

	Parrott City.	White River agency.	Los Pinos agency.	Montgomery.	Golden City.	Fort Garland.	Central City.	Pike's Peak.	Mount Lincoln.
Latitude	37° 22′	39° 58′	38° 12′	39° 00′	39° 44′	37° 32′	39° 48′	38° 50′	39° 21′
Longitude	108° 05′	107° 48′	106° 50′	106° 00′	105° 13′	105° 40′	105° 30′	105° 02′	106° 06′
Elevation, feet	8,633	6,491	9,290	10,783	5,729	7,945	8,300	14,147	14,200
January	....	21.8	....	17.86	....	18.46	24.05	2.1	6.0
February	....	26.2	....	24.45	....	23.37	....	4.5	....
March	....	28.6	....	19.78	....	33.63	....	4.5	....
April	....	41.0	....	29.75	49.77	42.75	38.53	14.9	....
May	....	54.7	....	41.28	61.00	52.41	49.27	21.4	....
June	....	64.4	....	....	67.57	62.23	62.73	31.0	....
July	....	63.9	....	....	73.33	66.61	67.90	35.7	45.0
August	....	64.8	55.8	....	74.73	64.34	....	35.9	43.0
September	....	58.3	46.2	....	65.80	55.61	56.33	32.1	36.0
October	....	49.0	....	....	....	43.97	....	25.0	28.0
November	....	35.8	....	....	....	30.88	35.83	10.8	18.0
December	....	26.8	....	19.58	....	20.05	37.30	9.7	15.0
Year	....	44.6	....	....	....	42.86	....	19.0	....

Of these stations, the first seven are situated in the plains; Cheyenne, Denver, and Colorado Springs are, however, within a very few miles of the foot-hills. Cañon City is in a well-sheltered bay in the mountains, but open to the plains. Its temperature is abnormally high. Of the other stations Golden City is immediately under the foot-hills. Fair Play, Los Pinos agency, Montgomery, Fort Garland, Central City, Mount Lincoln, and Pike's Peak are in the mountains. Parrott City is at the southwest foot of the San Juan Group, while the White River agency is in the plateau region.

Of the mountain stations, Fair Play is situated in the northwestern corner of South Park, under high mountains on the north and west. Montgomery is at the extreme head of the South Platte, about 12 miles north of the latter station, in a closely encircled mountain valley. The Los Pinos agency is in a broken country, between the Sawatch and San Juan Ranges. Fort Garland is situated on the eastern side of San Luis Valley, with high mountains on the north and east. Central City is in a narrow mountain valley. Pike's Peak and Mount Lincoln are among the highest peaks in the State.

Table of mean relative humidities.

Month.	Cheyenne, Wyo.	Colorado Springs.	Denver.	Dodge City, Kans.	North Platte, Nebr.	Santa Fé, N. Mex.	White River agency, Colo.	Cañon City, Colo.	Mount Lincoln, Colo.	Fair Play, Colo.
1875.										
January	66.3	63.7	56.3	63.8	70.0	51.1	......	44	......	......
February	63.2	73.4	46.6	72.3	72.7	48.4	......	58	......	......
March	62.6	53.5	48.4	59.8	61.4	36.3	......	40	......	......
April	60.6	53.6	46.8	63.9	66.2	24.1	......	......	......	......
May	42.5	45.3	38.4	62.7	59.6	25.3	51	......	......	......
June	32.7	42.3	28.0	58.5	56.7	19.8	50	......	......	......
July	58.4	68.3	55.7	67.1	66.4	54.9	60	......	59	46
August	52.0	63.4	46.7	66.6	59.2	46.8	55	......	57	61
September	57.3	64.4	51.3	62.7	60.0	56.1	63	......	......	44
October	40.4	48.0	33.5	52.9	55.4	23.7	54	......	......	......
November	62.9	55.9	59.8	53.0	67.8	54.1	65	49	......	......
December	51.4	44.9	43.8	58.4	64.3	47.7	72	50	......	......
Year	54.2	56.4	46.3	61.8	63.3	40.7	......	......	......	......

There is a generally increasing dryness of the atmosphere as well as decrease in the rain-fall as we proceed westward.

CHAPTER II.

ESTIMATED DISTRIBUTION OF ARABLE AND OTHER LANDS IN COLORADO.

From estimates based on the amount of land suitably situated for irrigation, the amount of water available for this purpose, and the character of the soil, it is estimated that in all Colorado there are 7,323 square miles, or 4,686,720 acres of tillable land. There is water enough to irrigate this area without the employment of reservoirs. This is 7 per cent. of the whole area.

Besides this, 55,000 square miles, or 52.6 per cent., is valuable as pasture land. This, however, is of very variable quality in different localities, grading into sage-brush (artemesia) and other brush barrens in such a manner that only an arbitrary line can be drawn between pasture and worthless lands.

The area covered by spruce and pine timber is 19.1 per cent. or 20,000 square miles; that covered by quaking aspens (*Populus tremuloides*), piñon pine, and the low, scrubby cedar so characteristic of the arid plateaus, is 13,500 square miles or 13.0 per cent., while 6.3 per cent. or 6,565 square miles may be classed as barren;—worthless, unless immense works be undertaken to reclaim it.

These areas are distributed as follows in the three districts of the State: The plains, with the exception of the arable areas along the streams and the Pinery on the Arkansas divide, are grazing land. There is no timber, except that mentioned above and scattering cottonwoods, in the bottom-lands. The grasses are mainly the nutritious buffalo and grama grasses. Cacti and sage flourish to some extent, and the Spanish bayonet is not unfrequently met.

The mountain region is pre-eminently the timbered region. Areas of arable land are, with few exceptions, of limited extent, being found only in small patches. Grazing land, though of greater extent, is also scattered about in small areas, while everywhere the principal growth is timber, and that mainly of the heavy spruce and pine. The inferior limit of this growth ranges about 8,000 feet, giving place below this elevation to piñon pine, or, in moister localities, to the quaking aspen. Its superior limit is the "timber-line," which, in Colorado, ranges between 11,000 and 12,000 feet above sea-level, depending mainly on the latitude.

The plateau region consists principally of flat or sloping mesas, covered with, according to their elevation, spruce and pine, quaking aspens, piñon pine, cedar, sage, sand, or bare rock. As their elevation decreases westward, so their aridity increases and the value of their natural productions becomes less. This region contains several large valleys, susceptible of irrigation in whole or in part. In this part of the State there is very little grazing land, except on those high plateaus where it would not be possible to winter stock.

GENERAL CONSIDERATIONS.

For successful agriculture there are necessary: a fertile soil, level surface, a sufficiently mild temperature, and the proper amount of moisture.

In Colorado, the first two of these conditions are fulfilled over a great area, probably two-thirds of the State. The third of these conditions diminishes this amount very considerably, as many fine mountain valleys are from their great altitude too cold to be useful as agricultural land, while the introduction of the last condition limits the arable land to a comparatively small amount.

The aridity of the atmosphere is so great and the rain-fall so light, so variable, and so sudden in its character, that, practically, irrigation is universally depended on, and is almost as much a matter of course as the sowing of the seed. There are small areas, as in the Wet Mountain Valley, where, from purely local causes, the rain-fall is sufficient to obviate the necessity for irrigation, but these are of small importance.

Another premise which holds good in nearly all cases, is that all irrigable land is cultivable, if not too high. The native products of the soil afford little indication of its barrenness or fertility. Because a soil naturally produces only sage and cacti, it by no means follows that only sage and cacti *can* be produced. To condemn the country because, under the natural conditions, it does not produce useful grasses, timber, &c., or even because it has all the appearance of a desert waste, is as unreasonable as to expect a tract of high land to produce cranberries.

Numberless proofs of the fact that the soil of what has been called desert is rich in the elements of fertility may be adduced. Salt Lake Valley was as unpromising as the "Great American Desert," Green River Basin, before the Mormons attacked it, but the application of water has made it one of the most fertile regions in the country. At Saint George, in Southern Utah, the victory over Dame Nature has been even more signal. Exception to this must be made in the case of land which is strongly alkaline. Unless this alkali be washed out, the land is valueless, and at present, and for many years to come, when good land may be had almost for the asking, there is no necessity for reclaiming this land. But the area of land in Colorado which is too strongly alkaline for use in agriculture is very small.

In the plains and the San Luis Valley, the only limit to the amount of arable land is set by the supply of water. All the water supplied to them by the South Platte, the Arkansas, the Rio Grande, and their numerous branches, can be used, and still there will be great areas waiting the magic touch of water to be covered with verdure. By husbanding in reservoirs the enormous supplies of this liquid which run to waste at the time of the June floods, which can be done in most cases at no very great expense, the amount of arable land can be immensely increased. At present, however, there is no need of undertaking such works as these.

In the mountains, the areas of level land so situated as to be irrigable are not in general sufficient to require all the water which is directly available, and in the plateau region the amount of irrigable land is, if anything, still less in proportion to the amount of water available.

An important factor to be considered in connection with the question of arable lands is the elevation. This sets immovable barriers to the growth of certain crops. A few facts regarding the upper limits of certain grains and vegetables have been collected. Mr. Byers, of Denver, editor Rocky Mountain News, says: "Wheat, barley, oats, potatoes,

turnips, peas, and the hardier garden vegetables, are safe crops at any elevation under 7,500 feet. Potatoes and turnips generally do well up to 9,000 feet. Wheat grows splendidly at as high an elevation as 9,000 feet, but above 7,500 feet it is a hazardous crop, liable to be injured by early frosts or snow. Oats grow well up to 9,000 feet, but generally do not ripen at this elevation."

Mr. E. L. Berthoud, C. E., of Golden City, Colo., writes me as follows on this subject: "Turnips grow and yield well up to 9,200 feet. Potatoes grow, but yield only fairly up to 9,200 feet, and at 9,000 feet the tops get frosted. Wheat does not ripen above 7,500 feet. Barley and oats scarcely ripen, and only in exceptional seasons, above 8,200 feet. Corn does not ripen above 5,700 feet. Wild grapes grow well up to 6,000 feet; cultivated grapes up to 5,800 feet. Pear-trees do well up to 5,750 feet. Buckwheat is so uncertain that it is not possible to give certain data as to altitude, but some has been raised at 7,400 feet. Except on the Arkansas River, Rio Grande, and lower Fontaine qui Bouille, corn is no crop in Colorado east of the (continental) divide."

These figures are liable to slight modifications from the influence of latitude and local causes, but in general they are correct.

AMOUNT OF WATER USED IN IRRIGATION.

The quantity of water applied by irrigation to various crops ranges within very wide limits in different parts of the earth. The requirements of the crops differ with the character of the season, whether wet or dry, and with the nature of the soil, whether clayey or sandy, &c.

An "inch of water" to the acre is a very common allowance in the State. An inch of water is the amount which will flow through an aperture 1 square inch in section in the course of a season; an amount which, of course, varies with the pressure from head or velocity.

In reference to this subject, Mr. E. S. Nettleton, of Pueblo, Colorado, has written me as follows: "It is impossible to give any rule for the quantity of water required to irrigate crops of different kinds. Land that has been irrigated for several years requires less water than new land. Clay lands require less than sandy lands. Very level land takes more water than sloping or rolling lands. * * * Crops which are sown broadcast require more water than those sown in drills or planted in rows. Early sown or planted crops, as a general thing, require less water than those sown or planted late. It is considered economical to irrigate in the latter part of the day or evening, especially in hot weather. Corn requires less water than almost any other crop, especially the Mexican variety. Oats and grass require the most. An inch of water to the acre is the rule of some. This may be half enough in some instances, in others it may be double or even three times the quantity required."

In regard to this question, Marsh, in his "Man and Nature," page 377, *et seq.*, says: "As near as can be ascertained, the amount of water applied to irrigated lands is scarcely anywhere less than the total precipitation during the season of vegetable growth, and in general it much exceeds that quantity. In grass grounds and in field-culture it ranges from 27 or 28 to 60 inches, while in smaller crops, tilled by hand-labor, it is sometimes carried as high as 300 inches," and adds, in a foot-note, quoting from Niel, "Agriculture des Etats Sardes," "that the practice in Lombardy is to give the equivalent of 32 inches of precipitation in 100 days, that being the estimated length of the irrigating season;" and that in Germany, quoting from Boussingault, "Economie Rurale," "Grass

grounds ought to receive 200 inches of water, or *six times* the total amount of precipitation, during the growing season." In Egypt ("Man and Nature," page 380) about 17⅓ inches, applied during 150 days, suffice. The report of the Commissioner of Agriculture for 1871 gives (page 280) the amount of water applied in France, from the Marseilles Canal, as one cubic foot per second for 70 acres. This is equivalent to an annual precipitation of 122.4 inches.

In the same report the following facts regarding the usage in Italy are given. For rice lands the equivalent of 16.2 inches per month, or of an annual precipitation of 194.4 inches is used; for summer meadows, 7.2 inches per month, or 86.4 per year; for maize, 2.4 per month, or 28.8 per year.

In the sub-Himalayan districts the practice is to allow one cubic foot per second for 218 acres, and this is very nearly the result to which Marsh arrives. (See report U. S. Geol. Survey, 1870, page 260.) This is equivalent to an annual precipitation of 39.36 inches. This, however, is far below the amount used in the West at present, but I have no definite comparable data on the subject.

This allowance of water takes into account roughly the amount wasted by evaporation and absorption by the bottom and sides of the ditches; an amount which, of course, differs in every case, and of which no certain estimate can be made.

The rain-fall is of so uncertain, variable, and sudden a nature, that I do not consider it best to take it into account in making estimates of arable land; particularly as the amount of water allowed is, as stated above, much below the practice at present, and as, in some localities, the rain-fall may, in any year, be absolutely nothing.

In a "Report on the Irrigation of the San Joaquin, Tulare, and Sacramento Valleys of California," the following facts concerning the amount of water per acre are given: The commissioners estimate that, on an average of crops and soils, one cubic foot per second will irrigate 200 acres, and quote the following statements: "In North India one cubic foot per second irrigates five acres per day. Taking the interval of irrigation at 40 days, we have the duty of 200 acres for one foot a second, for cereals. In Grenada, a canal for the Genil irrigates of wheat, barley, and vines, 240 acres per cubic foot. In Valencia, * * * about 200 acres per foot. In Elche, where water is very scarce, a cubic foot goes so far as to irrigate 1,000 acres. * * * Rice fields in different parts of the earth vary from 30 to 60 or even 80 acres to the cubic foot. In the heavy monsoons of India, 90 acres per foot is irrigated. * * * The grants for six recent canals in Spain run from 70 to 260 acres per cubic foot."

PROPER SEASON FOR GAUGING STREAMS.

Before giving any facts regarding the amount of the discharge of streams, with relation to their irrigating capacity, I wish to call attention to the fact that these measurements amount to very little, except as very general indications. The volume of water carried to-day is little indication of what it may be to-morrow. A heavy shower or a warm day in the mountains may temporarily double the discharge. At the time of the spring floods, in June, the amount discharged may be five, ten, or even twenty times that sent down in November, when the streams are at their lowest.

The proper time for gauging, with reference to the irrigating capacity of the stream, is at the end of July or early in August, about the close

of the irrigating season. Moreover, to obtain a result from which it would be safe to draw definite conclusions, the season should have been a dry one (for it is with the minimum supply of rain that we have to deal), and the normal regimen of the streams should not have been recently disturbed by rains. In our work, it is not possible to choose the time and conditions for making these measurements; but such measurements as we have made and collected will serve to give a rough approximation to the irrigating power of all the principal streams.

CHAPTER III.

CULTIVABLE AREAS OF COLORADO.

THE NORTH PLATTE DRAINAGE AREA.

The Platte, or Shallow River, as the name was rendered in English in the earlier days, drains the eastern slopes of the Rocky Mountains, from the forty-third to the thirty-eighth parallel of north latitude. Its branches head opposite to those of the Colorado and interlace with the head of the Arkansas.

In latitude 41°, longitude 101°, it divides into two branches, known as the North and South Platte. The former drains the North Park, Laramie Plains, the Laramie and Medicine Bow Ranges, and the northern part of the Park Range. Its course is very devious. Heading in the North Park, it collects its waters from all sides of this mountain-locked basin. Emerging from the park on the north, it pursues a course nearly north to its junction with the Sweetwater, in latitude 42° 20′, where it turns abruptly to the eastward, and after pursuing a course nearly east for a long distance, past the northern extremity of the Laramie Range, it bears gradually southward and pursues a course generally somewhat south of east to its junction with the South Platte. Its drainage area within the limits of Colorado is but 2,000 square miles, and consists of a part of North Park and the surrounding mountains. North Park is one of those high mountain valleys which form so characteristic a feature in Colorado topography. It is in shape nearly elliptical, its longer diameter lying nearly north and south and 35 miles in length. Its area is 914 square miles. The surface is very level, and in certain parts swampy. Its elevation, 7,500 to 7,700 feet above sea-level, together with the latitude, preclude the possibility of its being used to any extent as an agricultural area, and the same causes make it risky to attempt to winter stock there without hay and shelter. As a summer range it is unexcelled, as its native product is mainly bunchgrass, which grows luxuriantly. The arable area of the park is estimated at 232 square miles, while the remainder of the area of the park, 682 square miles, is available, as was stated above, as pasturage in summer.

DRAINAGE AREA OF THE SOUTH PLATTE.

The South Platte drains the South Park and the Front Range from latitude 39° to the northern boundary of the State. Its drainage area within the State is 20,800 square miles, and this is nearly all of its *entire* drainage area. The extreme head of this stream is directly under Mount Lincoln, in the northwestern corner of South Park. Its general course across the park is southeasterly, as are those of its principal branches in the Park, High Creek, the Little Platte, Trout Creek, and Tarryall Creek. All these enter the main stream within the Park, except the last, which joins it in the cañon, below its exit from the Park. The South

Platte leaves the Park near its southeast corner, cutting a cañon several miles long through the Puma Hills, which form the eastern wall at this place. Its course in this cañon is nearly northeast, changing to a course slightly east of north, which it holds not only until it clears the mountains, but as far as Greeley, at the mouth of the Cache la Poudre, in the plains. From the head of its cañon, where it leaves the South Park, to its emergence on the plains is a distance of 50 miles. In this part of its course it cuts diagonally across the whole breadth of the Front Range, here very broad, but broken up into a confusion of spurs and ridges that defy classification. Its course is alternately in cañon and narrow valley, the former predominating. In this part of its course it receives several good-sized branches—Tarryall Creek, which drains the northeastern part of South Park, Lost Park Creek, which collects the waters of a high, isolated mountain valley, and the North Fork of the South Platte, which flows through a long, narrow cañon-valley. These streams come in from the westward. From the other side the principal affluent is Trout Creek, which collects the drainage of Bergen and Hayden Parks, interior valleys of the Front Range. Its principal affluents, which head in the Front Range and enter it in the plains, are as follows: Bear Creek, with its branch, Turkey Creek; Clear Creek, of which Ralston Creek is a tributary; Saint Vrain's Creek, which, in the mountains, divides into Coal, North and South Boulder, Left Hand, Jim, and the North and South Saint Vrain's Creeks; the Thompsons, Big and Little, and the Cache la Poudre.

At the mouth of the Cache la Poudre the South Platte turns abruptly to the east, and, after holding this course to longitude 103° 30′, it turns nearly east-northeast, which course it holds to its junction with the North Platte.

The valley of the South Platte, from the foot of its cañon to the northeastern corner of the State, is 214 miles in length, with an estimated average width of 2 miles, or an area of bottom-land of about 400 square miles. Besides this bottom-land, the bench-land can easily be irrigated at no great expense. There is much more land within reach of irrigation than the river can supply with water. I have several measurements of the volume of water carried by this stream, none, however, made at the end of the irrigating season, and therefore they are poor indices of its irrigating capacity. They are as follows:

Where gauged.	Date.	Cubic feet per second.	Authority.
Six miles below Fair Play, South Park	July 3	388	Pearson.
Hartzell's Ranch, South Park (above mouth Little Platte)	June 29	367	Do.
Link's Ranch, where the road from Colorado Springs first crosses the Platte	June 23	1,015	Do.
Foot of Cañon	Sept. 8	1,400	Ebert.
Denver	December	492	Fisher.
Two miles above Denver (low water)		204	Holbrook.

At a short distance below the foot of the cañon the Great Platte Canal is taken out. The amount of water abstracted by this ditch should be added to the two last measurements to make them at all comparable with the others.

Judging by these measurements and the levels which its waters reach at flood and other times, I should say that near the end of July this stream carries about double the volume given by this measurement on September 8, or 2,800 cubic feet per second. Using the rule adopted for the sub-Himalayan districts, *i. e.*, that one cubic foot per second will

irrigate 218 acres, or that three cubic feet per second will irrigate a square mile, we shall find that the area irrigable by the South Platte is 933 square miles. Of this 624 square miles are in the plains and 311 square miles in the mountains, of which more hereafter. This plains area includes all the bottom-lands on the South Platte within the State, and also a part of the bench-land bordering the stream. I have little detailed knowledge of the bottom-lands of the river below Greeley, but presume that they keep pretty nearly the same average width as above this point. Above Greeley they are from half a mile to a mile wide, spreading out to three, four, or five miles at the mouths of some of its branches, making an average of about two miles in width, as was stated above.

The irrigating capacity of the branches of the South Platte from the west below the foot of its cañon, *i. e.*, in the plains, I estimate to be nearly equal to that of the South Platte itself, or, in figures, the amount of water carried by them is about 2,400 cubic feet per second, which represents an irrigable area of 800 square miles. Of these, the Cache la Poudre and its branch, the Box Elder, can irrigate 174 square miles, a large part of which is near its mouth, where, in the neighborhood of the town of Greeley, the bottom-lands spread out to a great width. Along the Big Thompson there is an irrigable area of 116 square miles; along the Little Thompson, 44 square miles. Saint Vrain's Creek can irrigate 174 square miles, half of which can be effected by the main stream, and half by its two branches, Boulder and Coal Creeks. Clear and Ralston Creeks can water 234 square miles; Bear Creek, 58 square miles. Of the streams which enter the South Platte from the South, Cherry and East Plum Creeks head in the Arkansas divide and carry but little water in proportion to the size of their valleys. The irrigating capacity of each of these is estimated to be 44 square miles.

West Plum Creek heads in the mountains and carries more water than these latter streams. Its irrigable area is estimated to be 72 square miles.

The courses of the branches of the South Platte, from the westward, in the mountains are almost entirely in cañons or narrow valleys. They contain no cultivable areas of any extent. Space for a ranch or two is found here and there; but, altogether, they are not of sufficient importance to be mentioned in this connection.

The following measurements of the amount of water carried by Clear Creek, at Golden City, were kindly furnished me by Capt. E. L. Berthoud, of the School of Mines, of that place:

	Cubic feet.
September 3.—Amount of water carried	374
August 27.—Amount of water carried	536
June 19 (flood height).—Amount of water carried	1,765

South Park is a table-land, very uniform in surface, with the exception of a few minor ridges, which traverse it in a direction slightly east of south, and in the southern part numerous volcanic buttes. Its shape is nearly elliptical, its longer axis being nearly north and south. Its length is about 50 miles and its width 25 miles. The area is about 870 square miles. The prevailing slope is from northwest to southeast. The elevation is, in the northern and northwestern part, 9,500 to 10,000 feet; in the southern part, 8,000 to 8,500. The mean elevation is not far from 9,000 feet.

The limits of the park are sharply defined by the mountains, which rise on all sides abruptly from the plains to the highest summits.

In general, the park is not well watered. Near its borders, especially on the northern and western sides, there is at all seasons an abundance of water, but throughout the whole interior part of the park water is scarce away from the main streams. Its surface is covered with bunch-grass of excellent quality, making it a first-class summer range for sheep and cattle, but the great elevation makes it hazardous to attempt to winter stock out of doors, except in sheltered nooks among the hills at the southern end. The same cause makes it of little value as an agricultural district, as only the hardiest crops can be matured. The cultivable area is estimated at 174 square miles, distributed among the South Platte and its branches, the Little Platte, High, Trout, and Tarryall Creeks.

In and about the course of the South Platte, from South Park to the plains, there are several valleys of limited extent, but whose aggregate area of tillable land is of considerable importance. On the river itself there is a valley 6 or 8 miles long, between the foot of the upper cañon and the mouth of Tarryall Creek, and another of about equal size a short distance above the mouth of the North Fork. The latter stream and Elk Creek each has a long narrow valley, containing a little arable land. On the other side of the river, Beaver, Trout, and West Creeks each has a small area of arable land. The whole area of cultivable land on South Platte drainage between South Park and the plains is 130 square miles.

Profile of the South Platte River from its head to Julesburg.

	From Julesburg.	Elevation.	Fall per mile.	Authority.
	Miles.	*Feet.*	*Feet.*	
Head	314	11,000	....	Hayden.
Fair Play, South Park	300	9,800	85.7	Do.
Mouth of Little Platte River	275	8,683	44.7	Do.
Foot of South Park (head of Upper Cañon)	264	8,165	47.1	Do.
Foot of Upper Cañon	254	7,921	24.4	Do.
Mouth of Tarryall Creek	244	7,326	59.5	Do.
Mouth of North Fork	226	6,110	67.6	Preliminary railroad surveys.
Exit from mountains	214	5,487	51.9	Do.
Denver	196	5,150	18.7	
Hughes	175	5,050	4.8	
Platteville	158	4,950	5.9	
Evans	141	4,725	13.2	
Julesburg	0	3,500	8.6	

Mean fall per mile in the plains, 9.4 feet.

DRAINAGE AREA OF THE ARKANSAS RIVER.

The drainage area of the Arkansas River in Colorado is 23,000 square miles, of which by far the larger part is in the plains. The stream rises in and near Tennessee Pass, flows at first about 25° east of south, through a valley 18 miles long and of a width varying from 1 to 4 miles. Then follow a few miles of cañon, below which the valley expands again to an average width of 4 miles, and continues thus to the mouth of the South Arkansas, or about 33 miles. Here it enters a cañon, or narrow valley, in which it is inclosed almost continuously to the plains. In one place this valley widens out in a beautiful little park, known as Pleasant Valley, about 10 miles long by 3 in width. The course of the river changes half a dozen miles above the mouth of the South Arkansas to

southeast, then to east-northeast at the foot of Pleasant Valley, then again to a course slightly south of east at the mouth of Currant Creek, and continues thus far out into the plains. At La Junta it turns to the eastward, and pursues an east course out of the State. It collects water rapidly in the mountains, while in the plains very little reaches it, even such streams as the Purgatoire, Apishpa, Saint Charles, and Fontaine qui Bouille running very low in the dry season.

The area of arable land on the Arkansas and its branches is estimated to be 1,979 square miles, or 7 per cent. of its drainage-area. Like the South Platte and Rio Grande areas, this is limited entirely by the amount of water available. Of this arable area nearly all, or 1,740 square miles, are in the plains, while the remainder is distributed in small mountain valleys on the main river and some of its mountain branches.

The important affluents of this river in the plains are, from the south, the Purgatoire (in vernacular, Picket Wire), the Apishpa, the Huerfano, with its branch, the Cucharas; the Saint Charles, with its branch, the Greenhorn, and Hardscrabble Creek.

On the north, the Fontaine qui Bouille is the only important branch. Beaver, Ute, and Turkey Creeks are of secondary importance. All these streams head in high mountains, and carry considerable amounts of water where they reach the plains. Their courses in the plains are long, and, through evaporation, sinking, and the present needs of irrigation, most of their volume is lost before reaching the main stream.

In the mountains the tributary streams are short, and most of their courses are down mountain slopes. The most important of them are Grape and Texas Creeks, the South Arkansas, Chalk, Cottonwood, Clear Lake, and Elbert Creeks, from the south and west; and Oil, Currant, Badger, Trout, and East Arkansas Creeks from the north and east. The Arkansas River has been gauged several times at Cañon City and Pueblo, at different stages of water. The results are presented in the following table:

Locality.	Date.	Cubic feet per second.	Authority.
Cañon City	End of August	2,050	Gannett.
Do	November	670	E. S. Nettleton.
Pueblo	do	608	Do.
Do	June	4,614	Do.

From these measurements it would appear that the amount of water carried by this stream at the end of July is about 2,600 cubic feet per second, an amount sufficient to irrigate about 870 square miles. This is much more than the area of bottom-land on this stream, but the slope of the bed is amply sufficient to take water up on the bench-land.

The Purgatoire is estimated to have 145 square miles of irrigable area; the Apishpa, 87 square miles; the Huerfano about the same in the plains, and the Cucharas 145 square miles. In these cases, the most economical placing of the arable land will be near the debouchure of these streams into the plains, as thus the great loss by sinking and evaporation will be avoided.

Huerfano Park, in which the Huerfano collects most of its drainage, is an elevated valley between the Sangre de Cristo Range on the west and the north end of the Wet Mountains on the northeast. Its average elevation is 7,000 feet. The surface is somewhat broken with benches and long swells. It is mainly valuable as a grazing area, there being

little timber in the park. The arable area is in narrow strips along the streams. Its total amount is estimated at 58 square miles.

The Saint Charles and Greenhorn Rivers can water 155 square miles. The larger part of this is at the east foot of the Wet Mountains.

The Fontaine Qui Bouille can irrigate about 145 square miles, distributed in a narrow belt along its course. Turkey Creek can water, possibly, 30 square miles, and Beaver Creek half as much.

Hardscrabble Creek flows north along the east foot of the Wet Mountains, receiving a number of little streams, making a continuous belt of irrigable land at the foot of this part of the range. The area is estimated at 37 square miles.

In the mountains there is a small irrigable area in Pleasant Valley of about 15 square miles. At the mouth of the South Arkansas there is, perhaps, twice as much arable land on the main stream and the South Fork. Farther up a narrow strip of arable land extends from the mouth of Chalk Creek up to the foot of the cañon, and above the cañon there is another narrow strip, extending up nearly to the head of the river. Each of these two latter areas is about 30 square miles.

Near the head of Oil Creek there is a valley containing between 40 and 45 square miles of arable land. Currant Creek has a narrow strip of arable land through a part of its course, amounting to about 15 square miles. On the other side of the river Texas Creek has a like area of arable land, situated in Wet Mountain Valley.

The following table gives the slopes of the Arkansas from its head to the eastern boundary of Colorado. The elevations are nearly all barometric:

Locality.	Authority.	From east boundary of Colorado.	Elevation.	Fall per mile.
		Miles.	*Feet.*	*Feet.*
Source in Tennessee Pass	Hayden	332	10,000	......
Mouth Colorado Gulch	......do	314	9,586	23.0
Mouth Lake Creek	......do	303	9,089	45.9
Mouth Pine Creek	......do	294	8,620	52.1
Mouth Cottonwood Creek	......do	281	8,317	23.3
Mouth Chalk Creek	......do	273	7,877	55.0
Mouth South Arkansas	Kansas Pacific Railroad	250	6,500	59.9
Cañon City	Denver and Rio Grande Railroad	197	5,300	22.6
Pueblo	......do	157	4,670	15.8
Mouth Apishpa River		116	4,371	7.3
Twenty-four miles above Bent's Fort		106	4,091	28.0
Near Bent's Fort		82	3,672	17.5
		65	3,537	8.0
		42	3,328	9.1
		21	3,166	7.7
East boundary of Colorado		0	3,047	5.7

THE SAN LUIS VALLEY.

This is the most southern of the succession of high mountain valleys, and is the largest of the four. Its shape is nearly elliptical, the longer axis lying about north and south. Its greatest length is about 140 miles, its greatest width about 50, while the mean width is 35 or 40 miles. The area is approximately 5,300 square miles. The elevation ranges from 7,400 to 8,000 feet. The southern third of this valley lies in New Mexico. It is with the northern two-thirds that we have to do. The surface of

this valley is as flat as a billiard-table. Variations of level are very slight, and are imperceptible to the eye. The beds of the streams are but slightly depressed below the level of the valley, generally but two or three feet. Most of the soil is sandy, especially toward the eastern side, where the sand is heaped up into dunes, against the mountains, and toward the south, while northward the sand decreases, and the soil becomes an adhesive clay.

San Luis Creek heads in the northern end of the park in a small subvalley known as Homan's Park. In its southward course it is joined by numerous little tributaries from the Sangre de Cristo Range, on the east. Most of these little streams sink in the porous soil in the summer, but each suffices to irrigate a small patch of ground at the foot of the mountains.

From the west, Kerber and Sawatch Creeks join San Luis Creek. The former has a few square miles of fine meadow-land along its course. The latter, a large creek, has fine, broad, meadow-like bottoms in the park, and a broad valley accompanies the creek 15 or 20 miles into the mountains. On this and the main stream, San Luis Creek, there are very large arable areas, compared with the apparent size of the creeks. From percolation through the soil, most of the bottom-land is more or less marshy, *i. e.* naturally irrigated.

This drainage system (of San Luis Creek), which includes the northern half of the portion of San Luis Valley, which we are considering, is not tributary to the Rio Grande, but, flowing down the valley near its eastern border to a point opposite the debouchure of the Rio Grande, it spreads out into an extensive swamp, having no outlet, save evaporation, overgrown with luxuriant greasewood, and developing here and there into small lakes or ponds, the water of which is a strong solution of alkali.

The Rio Grande heads in the heart of the San Juan Mountains. From the great snow-fields and the abundant showers which fall on these high mountains the stream grows rapidly, and at its entrance into San Luis Valley it is one of the largest streams of the State. From the point of entrance into the valley its course, which heretofore has been nearly east, gradually turns to south as the river slowly sweeps out into the middle of the valley. It has several good-sized tributaries in the valley, Alamosa and La Jara Creeks, and the Conejos, with its branch, the Rio San Antonio, from the west, and the Trinchera, Culebra, and Costilla from the east. Many more streams come down from the mountains to the edge of the valley, but are absorbed by the hot sandy soil.

The mountains on all sides are high, and send down a large amount of water into the valley, but the character of the soil is such that much of it is immediately absorbed.

The agricultural capabilities of this valley are measured solely by the supply of water. Were there a sufficient supply of that liquid, the whole valley could be made productive.

Prof. Cyrus Thomas, in the annual report for 1870, page 198, estimates the irrigable land at 25 per cent., without the use of reservoirs. In this estimate I agree with him. The amount of water which enters the valley north of the line of New Mexico, including the Rio Grande (which is by far the largest stream), will irrigate 1,291 or nearly 1,300 square miles. This is very nearly all the water which enters the valley. The irrigable area, then, 1,300 square miles, is practically the entire irrigable area of the whole valley, and is about 25 per cent. of the entire area. I, however, suppose all this water is used in that part of the

valley which is in Colorado, and thus increase the proportion of irrigable area to 32.5 per cent. of that portion of the valley.

This area is apportioned as follows among the different streams which enter the valley. The Rio Grande carries at the end of the irrigating season not far from 2,500 cubic feet of water per second. In that part of its course above the San Luis Valley there is but little irrigable land. There is a small area in Antelope Park, but it is too high for any but the hardiest crops to flourish. Below this the valley is narrow, and the amount of water used for irrigation would be so small that it need not be taken into account.

Our previous supposition, that one cubic foot of water per second will suffice to irrigate 218 acres, will not hold good in the case of the Rio Grande drainage area in this valley, for the soil is of the sandiest, and the waste of water would be enormous. Instead of allowing 3 cubic feet per second to the square mile, I should judge that 5 cubic feet would be none too much. This would give an irrigable area of 500 square miles by the river, and by its branches as follows: Alamosa and La Jara, 100 square miles; Conejos, about the same; the Trinchera, 72 square miles; the Culebra, 58 square miles; the Costilla, 29 square miles; and the Gata, 15 square miles.

Profile of the Rio Grande from its head to the foot of Taos Cañon.—(Hayden.)

	From head	Elevation.	Fall per mile.
	Miles.	*Feet.*	*Feet.*
Head in Cunningham Pass	....	12,090	....
Mouth of Pole Creek	4.5	10,790	228.9
Mouth of Lost Trail Creek	13.0	9,590	141.1
Antelope Park	28.0	8,990	40.0
Del Norte	88.0	7,890	18.3
In San Luis Valley	118.0	7,574	10.5
Do	148.0	7,415	5.3
Foot of Taos Cañon	....	7,301	....

DRAINAGE AREA OF THE SAN JUAN RIVER.

The San Juan drains the southern slopes of the San Juan Mountains. The headwaters of the main stream and most of its branches have long southerly courses in the mountains, where their valleys are narrow, and flanked on each side by high mountain spurs. The drainage area in Colorado is but 5,600 square miles, and this is, in large part, composed of the poorest country in the State. In and near the mountains the land is good and water abundant, but away from them, on the south and west, it is arid and desert. There is no water in the country, except in the main river, and a few insignificant holes and springs.

Most of the course of the San Juan itself through the arid and desert plateau is in New Mexico and Utah, as are also the lower courses of the more important branches.

In this drainage system there are, it is estimated, 392 square miles of irrigable land, distributed in narrow belts in and near the mountains.

On the Rio Navajo, the most eastern branch, there are a few square miles of irrigable valley, extending from near the foot of Banded Peak to the south line of the State.

The main stream (San Juan) has a fine valley, one to two miles in width, extending from the mouth of Cañon Creek to a point below that of the Rio Piedra, a distance of nearly 50 miles. The Piedra, below the

mouth of the Nutria, and the latter stream through nearly all its course, have fine but narrow valleys, and the Piedra has other small patches of land near its head. The Rio de los Pinos has a narrow valley extending, with short breaks to its continuity, far up into the mountains. The Animas and Florida have similar valleys. That of the former stream is particularly fine, spreading out in Animas Park to one of the finest mountain valleys in the State. The La Plata can water a strip of valley land 20 miles long by at least 2 in width. The arable land on the Mancos is mainly in a patch at the immediate foot of the La Plata Mountains; but, in addition, there is a very narrow belt along the river, for 25 or 30 miles above its mouth.

The other branches of the San Juan in the State, the McElmo and Hovenweep, are dry the greater part of the year from head to mouth, and their courses are in close cañon.

Profile of the San Juan River.—(Hayden.)

	From preceding.	Elevation.	Fall per mile.
	Miles.	*Feet.*	*Feet.*
Pagosa Springs	....	7,095	....
Mouth of Rio Piedra	38	6,000	29
Mouth of Rio Los Pinos	25	5,750	10
Mouth of Rio Animas	40	5,310	11
Mouth of Rio La Plata	3	5,297	4.3
Pictured rocks	11	5,180	10.7
	22	4,880	13.6
Mouth of Rio Mancos	21	4,700	8.6
	13	4,540	12.3
Mouth of McElmo Wash	12	4,510	2.5
Four miles below mouth of Montezuma Wash	11	4,390	11.0
Mouth	....	3,300	....

NOTE.—All elevations are barometric.

Profile of the Animas River.—(Hayden.)

	From mouth.	Elevation.	Fall per mile.
	Miles.	*Feet.*	*Feet.*
Divide at head	113	12,500	....
Head of Baker's Park	105	9,900	450
Foot of Baker's Park	97	9,400	28
Mouth of Cascade Creek	80	7,700	100
Head of Animas Park	70	6,900	80
Foot of Animas Park	56	6,6[illegible]0	21
Mouth of Florida	38	6,106	27
Mouth	....	5,310	21
Mean fall per mile from head of Baker's Park to mouth	....	....	43.7

NOTE.—All elevations are barometric.

Profile of the Los Pinos River.—(Hayden.)

	From mouth.	Elevation.	Fall per mile.
	Miles.	*Feet.*	*Feet.*
Weeminuche Pass	75	10,670	....
Trail leaves stream	69	9,888	130
Mouth of West Branch	60	8,688	133
Mouth of Vallecito Creek	48	7,688	83
Big Bend	42	7,288	67
Trail crosses	33	6,680	67
Mouth	....	5,750	28

NOTE.—All elevations are barometric.

Profile of the Rio Mancos.—(Hayden.)

	From mouth.	Elevation.	Fall per mile.
	Miles.	*Feet.*	*Feet.*
	62	9, 770	....
Merritt's ranch	52	7, 360	241
	38	6, 250	79
	32	5, 730	87
	22	5, 270	46
	12	4, 900	37
Mouth	....	4, 700	17

NOTE.—All elevations are barometric.

Profile of the La Plata River.—(Hayden.)

	From mouth.	Elevation.	Fall per mile.
	Miles.	*Feet.*	*Feet.*
Parrott City	43	8, 500	....
	38	7, 922	116
	22	6, 270	103
	10	5, 500	64
Mouth	....	5, 297	20

NOTE.—All elevations are barometric.

DRAINAGE AREA OF GRAND RIVER.

The Grand River unites with the Green to make the great Rio Colorado of the West. Its head is among the snow-fields of the western slope of the Front Range, in the northeastern part of Middle Park. Its drainage area in Colorado comprises 22,100 square miles. It consists of the Middle Park and the inner slopes of its mountain barriers, a large part of the Park Range, the western slopes of the Sawatch Range, the Elk Mountains, the north and west slope of the San Juan Mountains, the southern portion of the great White River Plateau, besides an enormous area of the broken plateau country farther westward. Its course from its head to its junction with the Green is, in general terms, somewhat south of west, at right angles to all the ranges and ridges. Consequently a large part of its course is in cañon, in forcing its way across the uplifts which it encounters. The arable area on the main stream is comparatively inconsiderable, being confined to cross-sections of the valleys which it traverses. The total area of arable land on this river and its branches is estimated at 1,200 square miles. Of this but 320 square miles are on the main river. This estimate covers all the level land which can be reached from the stream, and has no reference whatever to the volume of water carried by the stream, which is largely in excess of that required to irrigate this area. The river was gauged just above the mouth of the Gunnison on the 23d September, and found to carry 4,850 cubic feet per second. At the close of July it must carry at least 6,000 cubic feet. Other measurements, higher up the stream, have been made. Just below the mouth of the Eagle, a large branch from the Sawatch Mountains, it carried, *in November*, 871 cubic feet, and at the Hot Springs in Middle Park, near its head, it carried, in September, 802 feet. These last two measurements were made by Mr. S. B. Ladd, at that time attached to this survey.

Of the branches of Grand River, but one, the Uncompahgre, has sufficient land suitably situated to use up all its water.

The Middle Park, so called, is rather a collection of valleys, separated by high mountain ridges. On the east, the great wall of the Front Range separates it from the plains and forms the water-shed of the continent. On the west, it is shut in by the Park Range, through which, in a deep, narrow gorge, the waters, collected in this depression, find an exit. On the north and south, the ridges which separate the secondary streams of the Park rise to a considerable elevation, and are connected by saddles, forming the boundaries on those sides.

The principal branches of the Grand in the Park are the North Fork, Willow Creek, Troublesome Creek, and the Muddy from the north, and Frazer, Williams, and Blue Rivers from the south. All these are consequent streams, and all are in valleys of greater or less width, yet the amount of arable land on them is comparatively insignificant, being altogether but 30 square miles. That on the main river within the Park is 44 square miles, giving a total of 74 square miles.

The arable area on the Grand, in this part of its course, is in the form of a narrow strip, perhaps a mile wide, extending, with a few short interruptions, across the Park from east to west. Frazer River has a small area of arable land near its mouth and another some 12 or 15 miles above. The Blue River has a few square miles of cultivable land near its mouth. The valleys of the other streams in the Park contain no arable land. The elevation of the valleys in Middle Park range from 8,000 to 9,000 feet.

All these valleys contain large extents of pasture-land, extending to the bases of the mountains. The mountains are everywhere heavily timbered with pine and spruce.

Following the river down, the next arable areas of any extent are at the mouth and head of Egeria Creek. In these localities there are about 30 square miles of excellent land. The cañon which the river enters at the foot of Middle Park, and which opens out into a valley at the mouth of Egeria Creek, closes again below, and extends almost continuously down the river, to a point about 10 miles below the mouth of Roaring Fork. In this cañon Eagle River joins the Grand. This stream drains the north end of the Sawatch Range and part of the western slopes of the Park Range, heading opposite the Arkansas, and occupying the same consequent valley. Along it and two of its branches, Brush and Gypsum Creeks, it is estimated that there are 87 square miles of arable land, extending in narrow belts along these streams.

Roaring Fork drains the northern slopes of the Elk Mountains. Its course, and those of its numerous branches, are mainly in narrow mountain valleys. Its arable land consists of a small patch at the mouths of Hunter's, Woody, Castle, and Maroon Creeks, and a strip at the mouth of Rock Creek; in all some 15 square miles. Farther down, the Grand enters a broad valley, of which a very considerable part, about 72 square miles, can be irrigated and made productive. Its present product is mainly sage. Below, the river flows through a valley several miles wide, but utterly unfit for agriculture, as the surface is very uneven and cut by numerous arroyas. At the foot of this valley Plateau Creek enters the Grand. On this stream there is a small area of arable land.

Passing through another short cañon, the Grand emerges into that great valley which is known here as the Grand River Valley, farther up as the Gunnison, and still farther as that of the Uncompahgre. The

south end of this great valley is at the northern foot of the San Juan Mountains. Thence it extends nearly northwest, embracing, with its slopes, all the drainage of the Uncompahgre, a large branch of the Gunnison, which in turn is the largest branch of the Grand. Near the mouth of the Uncompahgre the Gunnison turns from west to northwest, keeping the course of the valley, and occupying a cañon on the west edge of the middle of the valley. At the mouth of the Gunnison the Grand takes its direction, following the northwestern course, and hugging the cliffs on the southwest side of the valley. At the mouth of Salt Creek the river turns sharply at right angles and flows off to the southwest. The valley, also, bends around to the west, in deference to the course of the Roan Cliffs, which here border it on the north. Altogether this valley has in Colorado a length, northwest and southeast, of 114 miles. Its width is variable. On the Uncompahgre it is widest, reaching 18 miles, while farther down it is from 6 to 12 miles in width. Its area is between 1,300 and 1,400 square miles. In the course of this valley we find all grades of natural fertility or barrenness. At its head, in Uncompahgre Park, the valley is filled with meadow grass, and, in season, is carpeted with flowers. The timber on the hill-sides is heavy spruce and pine. Going down the valley, the abundant growth of grass disappears to make way for sage; then that becomes stunted and scanty, and below the mouth of the Gunnison the valley is nearly destitute of vegetation, and presents a hard, smooth surface of white, sun-baked clay. Of this valley, the waters of the Grand River can reach only about 200 square miles, all which is situated on the northeast side of the river. The south bank is a vertical wall, of too great a height to surmount with the slight fall of the river. The soil of this part of the valley is a stiff, adhesive, bottomless clay, containing considerable alkali. Its elevation is about 4,500 feet above sea. This is the last arable area on the Grand in Colorado.

The Gunnison, from its mouth up to the mouth of Roubideau's Creek, *i. e.*, nearly to the mouth of the Uncompahgre, is in a cañon 600 to 1,000 feet deep, cut in the edge of the valley, with the exception of a mile or two at the mouth of Whitewater Creek. At this point there is a small area of meadow-land, easily irrigated.

The surface of this part of the valley is quite uneven, being much cut up by ridges running down from the Grand Mesa just east of it. This portion of the valley between the Gunnison and Grand is almost utterly worthless. The only part of that can be irrigated are the bottom-lands above the mouth of Roubideau's Creek. These average two miles in width, and are just high enough to escape floods.

In the upper portion, known as the Uncompahgre Valley, a different condition of things exists. The bottom-lands of the Uncompahgre average at least a mile in width. The bench is smooth, sloping with the river-bed approximately, and but 50 to 100 feet above it, while the fall of the river is quite rapid. The whole volume of the river can be used to advantage, with plenty of land remaining to await a change of climate.

In September the river was gauged at the agency, near the head of the valley, and found to carry 356 cubic feet of water per second. This implies about 600 cubic feet at the end of July; an amount sufficient to irrigate about 200 square miles. The elevation of this valley is from 5,000 to 6,000 feet.

The Gunnison River heads in the saddle connecting the Elk and Sawatch Ranges. Its drainage-basin, of 8,000 square miles, includes most of the western slopes of the Sawatch Range, the southern slopes of the

Elk Mountains, and the northern slopes of the San Juan Group. Though the drainage-area is not large, its mean elevation is very high, and it includes the loftiest and heaviest ranges in the State; and, in proportion to the size of its drainage-area, this river is one of the largest. It starts as a consequent stream, pursuing a course parallel to the wall of the Sawatch Range, which forms the eastern boundary of its valley. In this valley there is considerable irrigable land, but the great elevation (over 9,000 feet) and the stony nature of the soil (it is derived from morainal deposits) lessen its agricultural value materially. At the foot of this valley the river, re-enforced by several large mountain streams, turns at right angles and boldly pushes westward. At the outset it meets with difficulties, and is forced to cut a cañon through a heavy broad ridge which connects the Elk Mountains with a heavy westward spur from the Sawatch Range. That passed, it enters a broad valley, down which it meanders peacefully, receiving several large branches—Slate River and Ohio Creek from the north, and Tomichi Creek from the east. The first two head in the Elk Mountains, and have comparatively short courses. Their valleys, which in the mountains are narrow, widen as they approach the Gunnison, and help to swell the arable area of this valley.

The Tomichi heads about Mount Ouray, in the Sawatch Range, and flows nearly west throughout its course. Through most of its long course its valley is narrow, inclosed by high hills—spurs from the Sawatch Range. A narrow ribbon of arable land runs down this valley, almost continuously, from its head to its mouth.

A narrow belt of arable land extends down the Gunnison half a dozen miles below the mouth of the Tomichi, then the river enters a low cañon, in which it flows for about 15 miles. Then there is a short valley, extending up two creeks which flow in from the north, giving 8 or 10 square miles of good land. The White Earth, which comes in just above this valley, has a beautiful little valley about 20 miles above its mouth. And on Lake Fork, which comes in at the foot of this valley on the Gunnison, there is a narrow strip of arable land, commencing 15 miles above its mouth and running up about 10 miles.

Below the mouth of Lake Fork the river enters the Grand Cañon, 50 miles long, and, at its deepest, 3,000 feet in depth. Of the streams which join it in the cañon, none have arable areas of any considerable extent. Blue and Cebolla Creeks have small patches, and the North Fork, which enters near the foot of the cañon, furnishes a cultivable area of 10 or 12 square miles.

Below the cañon the river enters the Uncompahgre Valley, already described. The total amount of arable land on the Gunnison and its branches is 500 square miles.

The Dolores and San Miguel Rivers rise in the western part of the San Juan Mountains. They quickly reach the level of the plateaus and immediately bury themselves beneath that level, and flow, through nearly their whole courses, in cañon. The San Miguel River scarcely comes to the surface of the country at all during its course. In one place just above the mouth of Naturita Creek its walls diminish in height to little more than bluffs, and its valley widens out to about a mile, giving room for a few farms. On the Dolores there is a narrow strip about its southern bend, in the neighborhood of the mouth of Lost Cañon, another and larger area at the foot of Gypsum Valley, and a third in Paradox Valley. Below the junction with the San Miguel, at the mouth of the Unaweep Cañon, there is another irrigable patch. Altogether, the Dolores, including the San Miguel, has 145 square miles of arable land.

At the forks of the Little Dolores there is an area of about 30 square miles of good land.

Profile of the Grand River.—(Hayden.)

	From mouth.	Elevation.	Fall per mile.
	Miles.	*Feet.*	*Feet.*
Grand Lake, Middle Park	348	8,153	....
Forks	344	8,123	5.0
Hot Springs	320	7,715	7.0
Mouth of Muddy Creek	302	7,180	30.0
Foot of cañon in Park Range	295	7,000	25.7
Mouth of Eagle River	228	6,125	13.1
Mouth of Roaring Fork	209	5,743	20.1
Mouth of North Mam Creek	188	5,645	13.3
Mouth of Roan Creek	152	5,100	9.6
Mouth of Gunnison River	120	4,523	18.0
Head of Low Cañon	104	4,500	1.4
Horseshoe Bend	70	4,300	5.9
Mouth of Dolores River	52	4,250	2.8
Mouth	0	3,900	6.7

NOTE.—All elevations are barometric.

Profile of the Eagle River.—(Hayden.)

	From mouth.	Elevation.	Fall per mile.
	Miles.	*Feet.*	*Feet.*
Head in Tennessee Pass	62	10,418	....
Mouth of Homestake Creek	50	8,693	144
Mouth of Roche Montonneé Creek	45	7,856	167
Mouth of Gore's Creek	41	7,700	39
Head of cañon	29	7,065	53
Mouth	0	6,125	32

NOTE.—All elevations are barometric.

Profile of the Roaring Fork.—(Hayden.)

	From mouth.	Elevation.	Fall per mile.
	Miles.	*Feet.*	*Feet.*
Head	64	11,676	....
Mouth of Hunter's Creek	55	9,400	225
Mouth of Difficult Creek	48	8,241	166
Mouth of Castle Creek	43	7,942	60
Mouth of Frying-pan Creek	25	6,626	73
Mouth of Rock Creek	12	6,000	48
Mouth	0	5,743	21

NOTE—All elevations are barometric.

Profile of the Gunnison River.—(Hayden.)

	From mouth.	Elevation.	Fall per mile.
	Miles.	*Feet.*	*Feet.*
Head	200	11,000	....
Mouth of Pass Creek	185	9,869	75.4
Head of Upper Cañon	176	9,576	32.6
Mouth of Slate River	157	8,176	73.7
Mouth of Tomichi Creek	141	7,725	28.2
Foot of open valley	130	7,638	7.9
Mouth of White Earth River	123	7,450	26.9
Mouth of Lake Fork	112	7,213	21.5
Mouth of Cebolla Creek	97	6,800	27.5
Mouth of North Fork	62	5,405	39.9
Mouth of Uncompahgre River	45	5,100	17.9
Mouth of Roubideau's Creek	40	4,925	35.0
Mouth	0	4,523	10.0

NOTE.—All elevations are barometric.

Profile of the Lake Fork of the Gunnison.—(Hayden.)

	From mouth.	Elevation.	Fall per mile.
	Miles.	*Feet.*	*Feet.*
Head	59	13,260	
Valley	56.5	11,060	880
Mouth of South Branch	51	9,860	218
Mouth of Goodwin Creek	36	8,660	80
Mouth of Indian Creek	15	7,860	38
Mouth	0	7,213	43

NOTE.—All elevations are barometric.

Profile of the Uncompahgre River.—(Hayden.)

	From mouth.	Elevation.	Fall per mile.
	Miles.	*Feet.*	*Feet.*
Divide at head	78.5	11,100	
Head of small valley	74.5	9,700	350
Lower end of small valley	72.5	9,500	100
Lower end of cañon	68.5	8,000	375
Mouth of Dallas Fork	54.5	7,000	71.4
Uncompahgre agency	40	6,400	41.4
Ford of Salt Lake Road	29.5	5,800	57.1
Mouth	0	5,100	23.7

NOTE.—All elevations are barometric.

Profile of the Rio Dolores.—(Hayden.)

	From mouth.	Elevation.	Fall per mile.
	Miles.	*Feet.*	*Feet.*
Mouth of Lost Cañon	134	6,950	
Mouth of Disappointment Creek	83	6,500	32
In Paradox Valley	49	5,100	15
Mouth of San Miguel River	43	5,000	17
Mouth of Unaweep Cañon	21	4,600	18
Mouth	0	4,250	17

NOTE.—All elevations are barometric. Mean fall per mile, 20.1.

WHITE RIVER.

White River heads in high plateaus, which reach the timber-line. Its general course is westward, varied by occasional curves toward the north and south. From head to mouth it traverses plateaus, mainly inclined at low angles. Throughout it flows in a valley, through most of its course narrow, and limited by cañon-walls. The arable belt is narrow, nowhere exceeding a mile in width, excepting in Simpson's Park, where the White River agency is located. Here the valley spreads out, making an irrigable patch four or five miles in width by about the same length.

Of the branches of White River, the only one having any arable land in its cañon is that known as Piceance Creek, which has a narrow belt along it for twenty miles above its mouth.

The whole amount of arable land on the White River drainage, an area of 3,600 square miles, is 174 square miles, an area by no means sufficient to use up all the water brought by the stream.

YAMPA RIVER.

The Yampa, with its branch, the Little Snake, makes a rather more favorable showing. This stream heads in Egeria Park, opposite the head of Egeria Creek. It flows nearly north for about thirty miles, then turns abruptly to the west, and holds a tolerably straight course to its mouth. William's River, Elkhead River, and the Little Snake are its principal branches.

The drainage area of the Yampa is 5,900 square miles. It includes the Park and Elkhead Mountains, which occupy the eastern part of the drainage area. Besides these mountains, the country is generally made up of plateaus, somewhat broken and irregular. The beds of most of the tributaries are dry the greater part of the year.

The arable areas of this system are located on the main stream, Sage Creek, William's River, and the Little Snake, and on the first and last are of the most importance. The total amount of arable land is 319 square miles.

From Egeria Park to the mouth of Sage Creek there extends, with two short interruptions, a strip of arable land of width varying from one to five miles. About the mouth of Oak Creek there is a broad expanse of arable land, extending some distance up Oak Creek and other small branches in that neighborhood. Sage Creek waters a small area of valley, up which passes the road from the Middle Park to the Yampa River. On the main Yampa a narrow strip extends down the river about twenty miles from the town of Hayden, with a branch running five or six miles up the Elkhead River. Below this the river is in cañon for twenty miles, then opens out into a short valley, and again into a larger one, extending nearly down to the mouth of the Little Snake.

The Little Snake has two good-sized valleys. One, at its mouth, extends about ten miles up the stream, with an average width of two miles. Twelve or fifteen miles above its head the cañon opens again into a valley, averaging three miles in breadth and twenty-five miles in length within the State.

The Yampa was gauged about the middle of November, at the ford of the wagon-road from the White River agency to Rawlins, and was found to carry 364 cubic feet per second. This was at nearly the lowest stage of water, and indicates an abundance of water in the irrigating season for all the land which can be reached. No definite data concerning the fall of the stream are accessible, but it is known to be amply sufficient to take the water over any ground suitable for cultivation.

CHAPTER IV.

IRRIGATION IN COLORADO.

IRRIGATION DITCHES.

At present, in Colorado, most of the irrigating ditches are built by companies, who sell the water by the "inch" to the ranchmen. Much irrigation, also, is done, on a small scale, by individual ranchmen, and again, by co-operation, several large ditches have been made, and considerable areas of land placed under irrigation. I have succeeded in obtaining the details of construction of several of the largest of these ditches.

The Platte water canal is 24 miles long, extending from the foot of the cañon of the South Platte to Denver. Its original width at the head was 10 feet, and depth of water 2 feet, gradually decreasing in size as it neared the city. It has since been enlarged to a head width of 30 feet and depth of 3 feet. The slope ranges from 6 feet to 18 inches per mile.

Capt. E. L. Berthoud, of Golden, Colo., has sent me the following statistics concerning the Greeley, Evans, and Golden ditches:

Greeley, north side of the Cache la Poudre.—The Big Greeley ditch takes water from the Cache la Poudre River. It is 36 miles long. At its head it is 25 feet wide on the bottom, diminishing to 15 feet in width at Greeley. At its head it has 3½ feet depth of water, which is diminished to 3 feet at Greeley. For the first 22 miles the slope is 3½ feet per mile, with 2½ feet for the remainder of its course. The cost was $66,000.

Greeley ditch, on the south side of the Cache la Poudre.—This ditch is 11 miles long, 12 feet wide at bottom. The side-slopes are 1 to 1. Depth of water 2½ feet. The cost was $15,000.

Evans.—The town ditch is 5 miles long, 6 feet wide on bottom, side slope 1 to 1. Water is 2 feet deep. Slope of bed, 2½ feet per mile. Cost was $4,800.

The Big Evans ditch, on the south side of the South Platte River.—The length of the main trunk and branches is 45 miles. The main ditch is 10 feet wide at bottom; the water is from 2 feet to 1½ in depth. Side slope 1 to 1. Grade, 5 feet 4 inches per mile. Cost, $23,000.

Golden.—The town ditch is 6 miles long, 6 feet wide on the bottom, with 20 inches depth of water, and a grade of 10½ feet per mile. The cost was $17,000.

The following sketch of the *modus operandi* of irrigation at Greeley, Colo., written by Mr. N. C. Meeker, of the Greeley Tribune, describes the best example of irrigation in Colorado, if not in the West:

"The system of irrigation established at Greeley is different from any other in the world, particularly in regard to the right to water. The valley of the Cache la Poudre, in which Greeley is situated, was located and settled by the Union colony, composed of only 600 members, mostly heads of families. The location and purchase of the land was made by a committee, the president of which had control of a common fund,

amounting to over $100,000. With a portion of this money the land was bought, and with another portion the irrigating canals were constructed and a fence built around the whole domain, a distance of 45 miles. A canal 10 miles long waters the town and suburban property, being 15 feet wide and 2½ deep. It lies on the south side of the Cache la Poudre. The other canal is 36 miles long, 22 feet wide, and 5 feet deep. As these canals were paid for out of a common fund, the right to use water is attached to the fealty or to the soil, always being designated by the proper subdivisions of the section and township. The price originally attached to a water-right was $150, but, enlargements having been made, the cost has been added, and now the price is about $300. There is, therefore, no charge made for the use of water, but there is an annual charge for superintendence and repairs, usually about 25 cents an acre per annum. All other canals in the State are owned by companies, and the charge for water per acre, for one season, is $1.50 to $2, so that the cost of water for a year, for 160 acres, is more than a whole water-right in the Greeley canal. Now, while a water-right is attached to a particular piece of land, as above stated, it is permitted that the owner of a right may transfer his water to another piece of land for one season, or sell it for the same time to another farmer, the price being from $20 to $30, but increasing year by year. The volume of water which a water-right carries has been about 40 inches, delivered, say, under 6 inches pressure, and this one right will water 40 acres, that is, an inch to the acre. But as the average size of farms is 80 acres, a farmer either owns two rights, or hires another, or as frequently exchanges. Thus farmers on a common lateral agree that one farmer shall have the use of half a dozen water-rights for one day, or two days, then another farmer will take the same body of water, and so around, whereby an immense volume of water is obtained and a large area is more expeditiously irrigated than a smaller one would be in proportion. This arrangement works extremely well; indeed, the plan of making water nearly as transferable as a horse adds immensely to the capacity of the stream itself.

When irrigation first commenced great difficulty arose in dividing water, for those living along the upper part of the canal got most water; much of the time those living at the lower end got none, and disputes and complaints were general; nor could any light be had on the subject from those who had been irrigating elsewhere long before. This is a difficulty that seems general even in southern Europe and in Oriental countries.

To J. Max Clark, of Greeley, are the people indebted for a device which settles the whole question in an entirely satisfactory manner. Thus: The flumes from which water is admitted into the laterals are set down to the level of the canal, and being about 12 feet long and from 1 foot to 3 feet wide, they reach clear across the embankment. A gate set at a fixed uniform height admits the water from the canal, and thus a body of still water of a fixed depth is presented, and from this still water a gate on the field side is opened as high as will supply the number of water-rights claiming below. The rate or volume for each man is ascertained first by measuring the amount which the canal carries, and dividing this by the number of water-rights, whereby the whole of the water is used and each man on the canal gets his proper share. In a similar way farmers divide water at their fields from a common lateral. This principle for dividing water has been repeatedly demonstrated to be correct; perhaps the best proof is the unusual satisfaction which it gives. At each flume a notice is posted which indicates who have a

right to water below, and if a man has not settled his assessment or tax, he can have no water. At first locks were placed on the gates, but their use has been abandoned, because if a man should draw more than his share, the superintendent would quickly detect it by the gauge or figures on the lower gate; besides, when a man knows that he is getting what belongs to him, he is restrained by a sense of justice, and, moreever, the State laws are as strict in regard to stealing water as to any other property. Only one suit was entered, and that was abandoned upon the man agreeing to reform. It is to be noted that whenever a division of water is made, a definite amount is allowed for wastage by evaporation and soakage. This is about 50 per cent., which is found to be so nearly correct, that the amounts allowed to 300 farmers from 15,000 inches of water are as accurate as divisions of ponderable bodies could be.

During the height of the irrigating season, a period of two months, two superintendents traverse the canal from end to end daily, as if they were police, and one man is constantly on duty at the head gate to guard the dam and other works; for when the snow in the mountains is melting rapidly, the river is bank-full.

The fall of the large Greeley canal is $3\frac{1}{2}$ feet per mile, which is too much by 18 inches. The current is so extremely strong, that it is forded by teams with difficulty.

Gardens require irrigating once a week through the season; corn is watered three or four times by letting the water run through alternate rows; potatoes are watered twice, and that quickly, for much moisture is fatal to them; wheat and other small grains have two, sometimes three, irrigations, and the whole ground is covered with water. To raise a crop of wheat, it is required that with the rain-fall of spring, combined with the irrigations, sufficient shall be applied to cover the ground all over a foot deep. Water is let into the highest part of a field by broad, shallow ditches, which overflow. Some farms at Greeley lie so favorably and the arrangement of ditches is so proper, that water is let on at sundown in a huge volume, and it proceeds onward from ditch to ditch through the green standing grain, in appointed courses, and by sunrise 80 or 100 acres will be covered with water, without any help, when the gates are closed and other work is done.

COST OF IRRIGATION.

(From a paper in Agricultural Report, 1871.)

In Boulder County the cost is from 5 to 10 cents per acre each season, besides the first cost of a share in the works, which is from \$50 to \$100 each. The cost of repairs in the main ditch is paid by a tax on the shareholders, usually amounting to about \$5 a year. The laterals are owned by individuals and built at their own expense.

The charges of the principal ditch companies for water through the season are as follows:

	Per inch.
Platte Water Canal Company	\$3.00
Table Mountain	1.50
Farmers' ditch, Jefferson County	1.50
Ralston Creek Ditch Company	3.00

RESERVOIRS.

By storing the water which now runs to waste in spring floods, and utilizing it, a much larger area of land can be brought under cultivation.

The streams run full during the latter part of May and the most of June. The rise takes place more or less suddenly, corresponding with the rapidity of the melting of the snow in the mountains. After remaining at flood height not more than a month, the streams begin to decrease in volume, at first rapidly, then more gradually as the summer and fall advance. The lowest stage of the water is in November and December.

None of the streams of Colorado—and the same may be said of all streams of the West except the Colorado and Columbia—carry sufficient water to warrant the construction of large works in the form of reservoirs and irrigating canals. Several stupendous enterprises of this sort have been projected in Colorado, but fortunately neither government nor private capitalists have been induced to risk money in any such schemes.

The first of these in point of magnitude is proposed by Prof. Cyrus Thomas, and incorrectly attributed to this Survey. The author describes it as follows: "My plan is to throw up an embankment running north and south from the Arkansas to the North Platte, curving east and west, so as to follow a contour. Then, by throwing dams across the streams, turn the water into this reservoir. * * * An embankment or wall, averaging 30 to 40 feet in height, would, as the average slope here is about 6 feet per mile, form a lake 6 to 8 miles wide and 200 miles long. This would give a surface of some 1,200 square miles. * * * This would irrigate from 12,000 to 14,000 square miles." He proposes to build it on the east line of Colorado. This is truly a magnificent scheme, and one worthy to be ranked with the Chinese wall and other expensive follies of which the world has been guilty. The difficulty would be to get water for the reservoir. The total annual amount of water which the three rivers, the Arkansas and the North and South Plattes, could possibly deliver at the reservoir, even were none of it used above for irrigation, would be 73,873,000,000 cubic feet, an amount sufficient to make a depth of only about 2 feet in the reservoir. Now, as evaporation in that climate is at the rate of 5 or 6 feet annually, and the greater part of this in the summer, it can easily be seen that but a small part of the "12,000 to 14,000 square miles" will have any chance of getting irrigated; indeed, it would be difficult to keep the bottom of the reservoir moist.

Other plans are, in effect, to take the Arkansas and South Platte from their beds at the foot of the cañon of each stream and carry them over to the Arkansas divide bodily. The question, *cui bono?* is sufficient answer to these schemes. There is far more than sufficient good land in the immediate neighborhood of these streams to use up all the water which they deliver annually. There is no necessity whatever for carrying the water, in any case, more than 10 miles from the river. Other things being equal, the water should be used near the mountains, to avoid, as far as possible, loss by evaporation and sinking.

I should favor the plan of making a number of smaller reservoirs in the bottom lands. There are many places on the Arkansas and South Platte where, by the approach of the river bluffs to the stream on both sides, a dam could be built to connect them, at slight expense, and thus a considerable body of water imprisoned until needed. A succession of these along the streams, placed where the local topography and the needs of the land require, would serve the purpose of utilizing all the water which is annually sent down from the mountains.

As a favorable place to build a large reservoir, in which all the water of the Arkansas might be stored, I will mention a small valley in the midst

of the cañon of that river, known as Pleasant Valley. It is about 10 miles long by 3 in average width. The river passes through it, cutting its way out through a gap but a few rods in width, having vertical walls several hundreds of feet in height. At this point it could easily be dammed and the water drawn off as needed by the channel of the river.

A very favorable point for forming a large reservoir on the Rio Grande is near the foot of San Luis Valley, where the river, from flowing with a gentle current down the valley, nearly on a level with its general surface, suddenly runs into a narrow passage between two perpendicular walls of basalt. A dam at this point would collect all the water which the stream would annually bring down, but, owing to the very flat surface of the valley, the water would spread over a great area and the reservoir be proportionally shallow, and hence a large part would be wasted by evaporation.

It is unnecessary to dwell further on this subject of reservoirs, as the necessity for them is far in the future.

CHAPTER V

GRAZING LANDS OF COLORADO.

The native grasses of the West, the bunch or buffalo and the grama grasses, though more nutritious than most of our Eastern grasses, do not seem to have the same amount of vitality, and do not resist close cropping and trampling as well. The result is, that all ranges which are used nearly up to their full capacity are soon destroyed, the grass refusing to start up again. This is especially true of ranges used by sheep, who graze in close herds, and eat every thing eatable and constitutes the principal objection to their introduction. The cattle-men say that "sheep kill the range."

The grass over large areas of Colorado has thus been destroyed by overcrowding the range with cattle or by the pasturage of sheep.

It is said that the grass will recover its footing if left alone for a year or two. I do not know whether this has been demonstrated.

The same short sighted policy prevails in this case as in that of the buffalo and other wild game; to kill the goose that lays the golden eggs; to make as much as possible in the shortest possible time, without regard to the future.

PRINCIPAL GRAZING AREAS.

The plains, as mentioned above, are pre-eminently pasture-lands. Their principal natural products are the most nutritious of grasses—buffalo and grama. The character of the pasturage varies very much in different localities, ranging from the richest meadows to a comparative desert. Again, there are great extents of the plains absolutely without water, even in sufficient quantity for cattle, thus rendering considerable areas valueless for stock purposes. Still, by far the larger portion of this great area of 40,000 square miles is a valuable stock range. Anywhere on this range cattle, horses, and mules can winter, without protection or feed, with almost absolutely safety.

North Park contains about 700 square miles of fine grazing land. The elevation, about 7,600 feet, implies too cold a climate for stock to winter without assistance.

Middle Park contains several fine valleys of pasture-land. Those of the Grand, Muddy, and Troublesome, Frazier and Williams Rivers may be mentioned as the principal ones. The elevation of these valleys is from 8,000 to 9,000 feet, and this, coupled with the latitude, make the Middle Park practically valuable only as a summer range.

The South Park is used mainly in the same manner. In the southern and lower part, where the elevation reaches only 8,000 feet, and in sheltered nooks and little valleys in the mountains, cattle can and do winter, but the returning spring finds them in very poor condition, and an unusually hard winter or late spring often proves too much for them. The pasture area in South Park is 700 square miles, and the character of its grazing is excellent.

The San Luis Valley is at a much lower level. From a height of about 8,000 feet at its head it slopes very gradually to an elevation of 7,500 feet at the south boundary of the State. The latitude also is less, and the climate much milder than in the other parks, so that wintering stock out of doors is attended with no risks.

On the other hand, the grazing is poor. In the northern part of the valley, the part known as Homan's Park, the chief product of the soil is bunch-grass. Proceeding southward, this changes to grama grass and sage, the latter product making the greater part of the exchange. Near the south boundary of the State grass becomes very scarce, and sage proportionately abundant. The whole area of what may be called pasture-land is 2,700 square miles. There are fine grazing areas of limited extent in the valleys of several of the streams which flow into San Luis Valley, among which may be mentioned that of Sawatch Creek and Antelope Park, on the Rio Grande.

Wet Mountain Valley and the Huerfano Park contain very considerable areas of grass land, and make excellent ranges for stock, summer and winter.

The valleys of the Upper Arkansas contain some second-rate pasture-land. The upper valley is too cold for stock to winter out of doors. The climate of the lower valley, though the two differ but little in altitude, is much milder, and stock do well there, summer and winter.

An excellent summer range, and one, as yet, almost untouched, is found on the plateaus and in the valleys on both sides of the Gunnison, from Cimarron Creek up to the mouth of the Tomichi, and the valleys of the Gunnison River, Tomichi and Ohio Creeks, and East River, with the hills bordering their valleys. In this area the grass is luxuriant and abundant and water is plentiful. The surface is broken and uneven, and covered with scattered groves of timber affording protection against storms. The lower valleys of this area are undoubtedly a safe winter range. The height above sea ranges from 7,500 to 10,000 feet.

The Uncompahgre Valley is of little value for grazing. Except in the river bottoms, grass is very scarce. In the southern part of the valley, in and about what is known as Uncompahgre Park, there are a few square miles of excellent pasture. A narrow strip along the western edge of the valley also contains some grass. The lower part of this valley, known as the Gunnison and Grand River Valleys, shows a gradation from bad to worse. There is little grass in either part, and that little is so scattered that the cattle would grow poor in searching for it.

West of the Uncompahgre Valley, and separating it from the San Miguel and Dolores Rivers, is a high inclined plateau, sloping eastward toward the Uncompahgre. That portion of this plateau lying near its crest contains much fine grazing land, interspersed with groves of quaking aspen timber. From the elevation, cattle could not winter there.

The plateaus farther west, on the drainage of the San Miguel and Dolores, contain little land suitable for grazing; sage and piñon pine being the principal productions and water being extremely scarce. Exception to this must be made in favor of the country for 20 miles north and west of the San Juan Mountains. As far from the mountains as the supply of water in the small streams extends the grass is good, interspersed with groves of timber. Saucer and Gypsum Valleys contain some grama grass with white sage, and might do for a winter range for stock.

The Dolores Plateau, in the elbow-like bend of the Rio Dolores, contains quite a large area of fine pasture-land, interspersed with patches of heavy timber. The elevation, 8,000 to 9,000 feet, together with its

exposed location, presupposes severe winters, and makes it doubtful whether cattle can winter there.

The San Juan area presents very little good grazing land. Along the south foot of the La Plata Mountains there is a narrow strip of fine park-like country, with undulating broken surface, covered with bunch-grass and groves of heavy timber. In the hills between the Rios Animas, Pinos, and Piedra, this strip spreads out to a considerable width, and becomes of considerable importance. Its elevation ranges from 7,000 to 9,000 feet, and from its sheltered position, would make a safe winter range for stock. A similar belt of pasture-land exists at the foot of the mountains on the upper waters of the San Juan, Rio Navajo, and Rio Blanco. Aside from these areas, the San Juan district presents only very indifferent grazing land. Mesa Verde, on which there is much good grass, has practically no water on its surface. One small spring only is reported to exist there. The Great Sage Plain contains a little grass among the sage and piñon pine, but water is so extremely scarce that this can never be utilized. A small portion of this must be excepted from the general condemnation, that lying immediately southwest of the group of mountains known as El Laté, between the Mancos on the south and the San Juan on the west. Here the grass is more abundant than elsewhere on the Sage Plain, and the proximity to the San Juan supplies that desideratum, water.

Turning now to the middle portion of Grand River, between Middle Park and the mouth of the Gunnison, we find pasture-land of an indifferent quality, grading here and there into excellent grass land, on the plateaus at the foot of the Park Range, about the courses of the Grand, Eagle, and the lower course of Roaring Fork. The great valley of the Grand, at the mouths of North Mam and Rifle Creeks, is very poor in grass, and does not improve farther down, where it is narrowed between the North Mam Plateau and the Roan Cliffs. The broad valley of Plateau Creek and the lower northern slopes of the Grand Mesa are fair grazing land.

The drainage area of White River contains less heavy timber and more grazing land in proportion to its size than any other such area west of the mountains. The high plateaus about its head, which reach in many places to the timber-line, are mainly covered by heavy timber, with some patches of grass of considerable extent. West of this the part of the drainage basin on the south side of the river consists of an inclined plateau, sloping gently to the river, and reaching a crest above the desert valley of the Grand, before mentioned. This is the Roan or Book Plateau. Its surface is much cut up by cañons. Every stream or dry wash flowing to the White carries itself, as soon as possible, far below the surface. All over this surface grass is abundant, interspersed with sage, piñons, and, near the crest, a little quaking aspen, spruce, and pine. Water is scarce and not easy to reach. Douglass and Pice-ance Creeks are constant streams, but the others cannot be relied on. On and near the crest springs of excellent water are found at intervals.

Simpson's Park, in which the White River agency is located, contains a small area of fine meadow-land. All the hay for the use of the agency is now cut there.

North of this little valley the hills between the White and the Yampa, known as the Danforth Hills, are covered with good pasturage on both slopes. West of these hills the country between the White and Yampa is a series of broken plateaus, almost waterless, and desert; in some places there is a little grass among the sage but the country is mainly covered with sage and piñon pine.

The Yampa, from its head in Egeria Park down to the mouth of William's Fork, is bordered on the west and south by a broad strip of pasture-land of excellent quality. On the north side of this river, and east of the Little Snake, the whole country, from the foot of the Park and Elkhead Mountains, consists of plateaus with rolling surface and little timber. These plateaus are mainly covered with sage, among which is much excellent grass. The quality of the pasturage varies greatly, being poorest in the interior of this area and best near the margin, at the foot of the mountains, and in the neighborhood of the rivers. These plateaus are too high and exposed to serve as a winter range, but in the valleys of the Yampa and Snake there is sufficient pasturage for the winter for large herds.

West of the Little Snake the country is very similar to that last described; indeed, the above remarks will apply equally well to this area. The Escalante Hills are well covered with heavy timber.

REPORT OF GEORGE B. CHITTENDEN, C. E., TOPOGRAPHER OF THE WHITE RIVER DIVISION, 1876.

LETTER OF TRANSMITTAL.

WASHINGTON, D. C., *February* 15, 1878.

SIR: Herewith I transmit my report of the topographical work done by the party under my direction during the season of 1876 in the White River district.

The country surveyed was almost entirely unknown, and our work is found to be of a radically different character from what had been generally supposed. Aside from its geographical importance, there was in it but little of scientific interest. I have therefore confined myself principally to a description of the surface characteristics, and the course pursued by us in working the district.

Our headquarters for the season were made at the White River Ute Indian Agency. I wish to express through you my hearty thanks to the agent, Mr. Danforth, and his wife, for the universal kindness and hospitality with which we were received, and for the many favors which they were able to extend to us.

Trusting that the results of the season's work may prove satisfactory, I remain your obedient servant,

GEORGE B. CHITTENDEN.

Dr. F. V. HAYDEN,
United States Geologist in charge.

TOPOGRAPHICAL REPORT ON THE WHITE RIVER DISTRICT.

The White River Division left Cheyenne by rail for Rawlins station on the 14th of August. It consisted, besides myself, of Dr. Endlich, geologist, Mr. E. N. Dickerson, barometric observer, two packers, and a cook; I myself doing the topographical work. All the animals, instruments, and pack outfit, together with our two and a half months' supply of provisions, having been shipped as freight, we were obliged to remain over one day at Rawlins before beginning our march to the White River Indian agency, the point selected as headquarters for the season.

The area assigned us lay to the south and west of the agency and consisted of a narrow belt of country, bounded on the south by the "Book Cliffs" and on the north by White River. On the east, the line was the western limit of Mr. Marvine's work of 1874, while the western line was the meridian of 109° 30′ west longitude. These limits enclosed about 3,000 square miles.

The march from Rawlins Springs to the White River agency occupied nine days, as the pack animals were necessarily heavily loaded. We were therefore unable to begin our work until the 27th of August.

GRAND HOGBACK.

On that day we occupied Mr. Ladd's Station 29 of 1874, in order to connect our triangulation with that done by him.

This station lay about four miles southwest of the agency and was made the day after our arrival without moving camp. The following day we moved to the south in the direction of Grand River, continuing our work along the western border of Marvine and Ladd's district of 1874 and connecting our topography with theirs. The route travelled was a broad and well-worn Indian trail which led through a continuous valley at the eastern base of a line of hogback hills, which extend from White River to and across the Grand in an uninterrupted chain, forming a topographical feature so remarkable that we have named it the "Grand Hogback Range." This Hogback Range is broken three times by mountain streams flowing down against it from the east, and once it is broken by a narrow pass through which at present but little water finds its way.

All of these breaks or gaps are walled by high and rugged cañon sides, but the steepest and by far the most picturesque is the third from the north. A very considerable stream pours through this gateway, and although its flow on either side of the gap is comparatively gentle, it rushes through the cañon pass with all the roar and thunder of a mountain torrent, adding in no small degree to the grandeur of the scenery. This cañon, although short, is one of the most picturesque in all this portion of Colorado. At the head of the cañon the trail forks, and one branch, passing through, leads down over low terraces or along the side of the stream, through a broad sterile valley, to the Grand River. This valley, from its thick carpeting of prickly-pears and other low-growing *cacti*, has been named "Cactus Valley." Considerable por-

tions of it can be readily irrigated, and from the mild climate which it must possess in the winter, it can easily be seen that it will prove available for agricultural purposes, and that it will produce many crops that it is impossible to raise in the valley of White River. The left-hand branch of the trail continues southward on the east side of the hogbacks, to fork again some six miles farther on, one branch leading through the already-mentioned nearly dry pass to Cactus Valley, while the main trail keeps on down the valley without interruption to the Grand.

On the east side of the hogbacks and nearly opposite the dry pass, just referred to, a single family of White River Utes has made its home, having occupied for many years the same sheltered nook. The family consists of some ten or fifteen members, and the settlement is known at the agency as the "Old Squaw's Camp," from the energetic old Indian woman who seems to be its leading spirit. There is most excellent hunting in the immediate vicinity of the camp, and from the location the winter weather experienced must be mild. This family cultivates a small patch of ground, and possesses a herd of 50 or 75 head of cattle and an equally large herd of ponies. Although these people are still housed in the traditional *tepee* or *wick-e-up*, they seem to have virtually withdrawn of their own accord from the nomadic life pursued by most of the tribe.

On both sides of the Grand Hogback, along its entire extent, there is good pasturage, but the amount of arable land is very limited. There are but two points which seem to have been much used by the Indians as camping places. The highest point on the trail leading from White River to Grand River is 7,733 feet above sea-level. The highest measured point in the Hogback Range is about 20 miles south of White River and attains an altitude of 9,311 feet above sea-level. Seven topographical stations were made along the Hogback Range and to the east of it.

ROAN OR BOOK PLATEAU.

Marching through the range near the headwaters of Pi-ce-ance Creek, we entered the plateau region that stretches from tho hogbacks westward. Where Pi-ce-ance Creek cuts through the hogbacks it is a stream of five or six feet width; but the amount of water rapidly diminishes as we follow its course, until, at a point some six miles from the range, it entirely disappears.

We had been able to learn absolutely nothing as to the character of the district which we now entered. From the north and east it had shown only as an undulating, yellow plateau, apparently treeless, and cut by numerous deep washes or cañons, with sloping, grass-covered sides of the same yellow hue. From the south no idea of it could be obtained, since the summit of the plateau was entirely invisible from the lowlands of Grand River, only its edge showing as a rugged, inaccessible, and apparently unbroken line of bluffs, upward of 2,000 feet in altitude, which had long been known as the Roan or Book Cliffs.

Unable to find any encouraging signs of water on the summit of this unexplored plateau, but knowing that it was absolutely necessary to our work that the party should visit it, we followed Pi-ce-ance Creek until its bed was perfectly dry, and then, turning up one of the dry gulches to the left, struck for the head in the hope of finding running water or springs. For some miles we followed the bed of the stream, but, toward the middle of the afternoon, were forced by the increasing ruggedness of the cañon-walls to climb out and take our course along the summit of the plateau, marching toward the head of this dry water-

course between two of its principal branches. The summit of the plateau was grass-covered and favorable for travelling, rising gradually toward the southward. It was almost nightfall when we reached the heads of the gullies, but here we found small groups of aspen trees, and by descending 400 feet into the cañons found little trickling streams of pure water. The cañon bottoms were too narrow for camping purposes as well as inaccessible to our loaded pack-mules. We were therefore obliged to make our camp on the summit of the plateau, and carry up by hand all the water for camp purposes, a distance of 400 feet. We were able to lead down our thirsty animals after they were unloaded, enabling them to drink. Excellent grass was abundant all over the summit of the plateau, and we were well satisfied with the camp, promising, as it did, the easy working of the plateau region, which formed a considerable portion of the district to be worked during the season. As we followed the summit of the plateau in the days following we found abundant water in nearly all the heads of the Pi-ce-ance drainage and also in the branches of Parachute Creek, a stream heading opposite; the former flows southward to Grand River.

After five days spent in working the country from the water divide of the plateau, always travelling on well-beaten Indian trails, we again descended to Pi-ce-ance Creek, reaching it some 15 miles below the point at which we had left it. We then followed it to White River over an indifferently good trail. The creek where we reached it this second time was quite a considerable stream, winding with a very sluggish flow through a sage-brush-covered bottom-land. It would perhaps average 30 or 40 square feet in cross-section and was not readily fordable by our pack-train. Most of the water in the creek was supplied by two or three branches from the northwest. Pi-ce-ance Creek throughout its entire drainage area has very little wood or timber of any description. A few patches of aspens and occasional pines near its heads, and a few piñons and junipers on the low bluffs near its mouth, comprise all the areas of timber. Nearly everywhere outside of the cañons there is an abundance of good grass.

On the 11th of September, having visited the agency and taken up a month's supply of provisions, we took up our line of march down White River, to visit and work up all the western portion of our distrct. The agency is located on White River, near its exit from the mountains, at the head of a series of open parks or bottoms which continue at intervals for more than 20 miles below the agency along the course of the river. These bottom-lands are in places nearly a mile in width, all easily irrigable, and affording many thousand acres of most excellent arable land. Mr. Danforth had cultivated about 40 acres of land for the use of the agency and was raising potatoes, beets, carrots, and turnips, besides quite a large field of oats. White River has ample irrigating capacity for all the available land along its entire length.

Having followed down White River for about 40 or 45 miles, we left it and turning southward marched toward the summit of the plateau, up an even, gentle slope. We reached the summit level the same afternoon, after travelling about 20 miles from the river, and were surprised to find ourselves on the edge of a precipitous cliff which continued impassable for a distance of 20 miles north and south. This cliff or bluff, with its slopes, was at least 2,000 feet in altitude and overlooked a broad area of low country drained by a creek which later was named by us Douglas Creek, after the head chief of the White River Utes. The bluffs were named Cathedral Bluffs. Following the bluffs around to the south and west we again reached the divide between White and Grand

Rivers and followed it to the westward, always finding well-worn trails, from which we worked the topography on either side as far as we were able to reach.

From the head of the western branch of Douglas Creek the plateau character was almost entirely lost, often affording only a narrow backbone for the trail to follow, while, in consequence of this, water became scarcer, obliging us on three occasions to descend into the cañons, a vertical distance of upward of 2,000 feet, with the whole train, to find camping places. The general topography of the country all through this part of the district, and indeed as far as the western limit, is that of the narrow ridge already spoken of as extending east and west between the lateral drainage of White and Grand Rivers, respectively; these lateral branches heading against the ridge opposite each other, and flowing in deep cañons north and south.

Our second approach to White River was down the first of these lateral streams, westward of Douglas Creek, which was named Evacuation Creek. The stream has more or less water in all its numerous heads, but all the upper portion of the main stream is dry for a distance of at least 12 or 15 miles, when the bed begins to show signs of moisture, and at last contains a small running stream of two or three inches depth, which continues uninterruptedly to its mouth, a distance of nearly 25 miles. The water is for the most part bitterly alkaline, utterly unfit for human use, and refused in any quantity by the animals. The water is much more unpalatable than that of the celebrated Bitter Creek of the Union Pacific Railroad. About the heads of this creek the bluffs are covered with a rich growth of grass, and the cañons contain both pines and aspens, but near the point where it first becomes dry the pines give way to junipers and piñons, and both cañons and bluffs are covered with their scraggy growth. The cañon walls are only a few hundred feet high, and the creek bottom is broad and generally covered with a growth of sage-brush. As the mouth of the creek is approached the piñons and cedars in turn give way to a growth of low brown grass, the cañon-walls being smooth and unbroken and attaining a height of only 200 or 300 feet. A tolerably good trail follows the entire length of the stream.

Between the mouths of Douglas and Evacuation Creeks, White River is in a close cañon which falls away a little near the mouth of the latter creek, and renders the approach to the river easy, while small, open grassy parks dotted with huge cottonwoods afford most delightful camping-places that are very refreshing after the desert-like country that lies to the southward. From the mouth of the Evacuation Creek, White River remains in cañon as far as the limits of our work carried us, *i. e.*, very nearly to its mouth. We followed the river through this cañon four short day-marches, and found the greatest difficulty in getting through, being sometimes compelled to cross the river four or five times within a single mile. The walls of the White River Cañon are seldom more than 800 feet in height, and are often broken away, especially on the south side, into the most grotesque and picturesque forms, giving many gigantic representations of animals and human heads and figures, all ludicrously full of action, as well as many forms resembling towers and other grand architectural forms.

We worked as far south from White River as was desirable, and always found only a broken desert country without any sign of water. There is no considerable drainage entering White River from either side below Evacuation Creek for a distance of 30 miles, when we reach a fourth main lateral branch, which was named Two-Water Creek. It

enters the White through a low-walled cañon of only about 300 feet depth, and at its mouth has no water. This creek being very near our western line, we left the White River at its junction, and marching up the stream, a third time sought the crest of the plateau. There is no good trail up this stream, and for 18 or 20 miles not the least sign of water. The sage-brush in the valley was often well-nigh impassable even by saddle-animals, owing to the heavy growth, as it reached to the shoulders of a mounted man. After marching until late in the afternoon we came to the principal forks of the stream, about 25 miles from its mouth, and there found water, the peculiarity of which led us to name the creek "Two-Water." Down the left-hand branch came a little rill of water which at the junction spread out into shallow lakes or pools of only one or two inches depth. This water was bitterly alkaline, while the right-hand branch, although containing no running water, had along its bed numerous pools of as pure water as could be desired by any one. The pools of sweet and bitter water approached within five or ten feet of each other, retaining all their marked differences of character.

From this point it seemed impossible to follow the valley of either branch on account of the mire and sage-brush; so, having camped at the junction, we next morning climbed out of the cañon and reached the summit of the plateau between the forks of the creek. Finding no trail, we nevertheless had very good travelling, but were obliged to camp after dark near the summit of the plateau, with only a little pool of water for our entire supply, and this utterly inadequate for the thirsty animals. It was not until noon of the following day that, after most diligent search, we succeeded in finding, on the Grand River side of the divide, a small spring, by which we made a comfortable camp for the refreshment of ourselves and our animals. The western end of the plateau is far drier than the eastern portion, and although we saw some deer around us, we were unable to find any water except in the little spring by which we were camped. The whole country is exceedingly dry, and cañons a thousand feet in depth, in whose dark recesses one would naturally expect cool running streams, were universally as dry as dust.

Riding westward from this camp, along the summit of the plateau, I discovered and located a group of bitumen springs, visited later by Dr. Peale, and carried our topographical work to the western limit of the district. Near the bitumen springs, later in the season, Mr. Gannett found a spring of clear water, which seemed to have been much used by the Indians as a camping place. From this camp we turned eastward along the divide, which is here merely a narrow backbone, which on the south breaks off sharply into steep bluffs, and on the north sends out long tongue-like extensions between the almost numberless cañons in which Two-Water and Evacuation creeks head.

After making numerous stations on the divide as we marched eastward, we finally turned for the last time toward White River, following down the main western branch of Douglas Creek, a stream not followed before. In marching northward we found good water for 20 miles, until a point near the vicinity of the main forks was reached, where running water ceased and thence to the mouth was found only in pools. A little earlier in the season there is probably running water the entire length of the stream. There is a good Indian trail the whole distance, but grass is small in quantity, the valley being covered with grease-wood and sage-brush of very sturdy growth.

There are many lateral branches of Douglas Creek, all coming in through rugged litte cañons of 300 to 500 feet in height, and all utterly destitute of water. The valley of the main creek is often half a mile or

more in width, usually limited by steep bluffs, being in no place of a marked cañon form. The walls become less well defined near the mouth, and when the creek at last approaches the White, it is through low terraces, upon a broad, open bottom-land, the largest in the entire course of the White, with perhaps the exception of Agency Park. An attempt was made some years ago to start a colony in this valley, but for some reason the attempt was a failure. The ground is now within the limits of the reservation for the Ute Indians.

Passing down the river through this valley, we entered the cañon of the White, already referred to, and connected the work with that done before from the mouth of Evacuation Creek. Then turning up the river we completed the remaining small unworked portions along its borders, and reached the agency October 11, having in forty-eight working days completed the topography of 3,800 square miles of country, making in the course of the work 41 main topographical stations, besides 16 auxiliary ones, and travelling 1,000 miles within the district.

RETURN FROM THE FIELD.

On the 12th of October our party left the White River agency to return to the East, and choosing the route through the Middle Park instead of that via Rawlin's Springs, avoided the expense and trouble of railway shipment. This route formed a most pleasant line of march, abounding as it did in wood, water, and grass, three elements of comfortable camping much lacking in the other route. The extra time between the agency and Cheyenne consumed only two days.

Dr. Endlich and Mr. Dickerson left the party at Boulder City, while I remained with it one more day and dismissed the men and animals at the upper crossing of the Big Thompson River, that they might proceed directly to Cheyenne, while I completed a few hundred square miles on the plains bordering the mountains. I was engaged ten days in working the topography of this additional area, living at the towns and settlements as I came to them. The topography was very simple, and I was enabled to cover 800 square miles in the ten days, riding about 350 miles, and closing the season's work at Denver about the last of October.

List of elevations in the White River district.

Locality.	Approximate latitude.		Approximate longitude.		Elevation in feet.
	°	′	°	′	
Station 2, west end of White River Plateau	39	50	107	53	9,283
Station 3, west end of the White River Plateau	39	46	107	51	9,904
Station 4, Grand Hogback Range	39	43	107	54	9,811
Station 5, Grand Hogback Range	39	37	107	43	8,068
Station 6, Elk Creek north of Hogback Range	39	40	107	39	8,533
Station 7, Roan or Book Plateau	39	40	108	02	8,625
Station 8, Roan or Book Plateau	39	34	108	13	8,719
Station 9, Roan or Book Plateau	39	37	108	18	8,807
Station 11, Roan or Book Plateau	39	44	108	32	9,035
Station 13, bluff on east side of Pi-ce-ance Creek	39	53	108	14	7,275
Station 14, butte in angle of White River and Pi-ce-ance Creek	40	04	108	12	7,210
Station 16, bluff on south side of White River	40	08	108	19	7,205
Station 17, north of Cathedral Bluffs	40	03	108	32	8,407
Station 18, north end of Cathedral Bluffs	39	58	108	37	8,704
Station 24, Twin Buttes	39	35	108	51	8,950
Station 26, White Face Butte	39	46	109	01	7,241
Station 29, south of White River, west of Asphalt Creek	39	50	109	18	6,413
Station 31, east side of Two-Water Creek	39	48	109	21	6,310
Station 32, between forks of Two-Water Creek	39	43	109	19	6,440
Station 34, summit of Roan or Book Plateau	39	26	109	10	7,343
Station 36, Rabbit Hills	39	46	108	50	8,430
Crest of Roan or Book Cliffs on Grand River, below Cactus Valley					8,400 to 8,600
Summit of Roan or Book Plateau overlooking Grand River Valley					7,904 to 8,850
Cactus Valley of Grand River					5,445
White Mountain					8,400
Pass from Flag Creek to Riffle Creek					7,733
Mouth of Evacuation Creek					5,124
Mouth of Two-Water Creek					4,856
Forks of Two-Water Creek					5,838

REPORT OF GUSTAVUS R. BECHLER, TOPOGRAPHER OF THE YAMPA DIVISION, 1876.

LETTER OF TRANSMITTAL.

WASHINGTON, *February* 18, 1878.

SIR: I have the honor herewith to submit to you the topographical report relating to the district assigned the Yampa River Division under my charge during the field season of 1876.

After leaving the rendezvous camp on Owl Creek, 12 miles south of Cheyenne, August 16, 1876, we proceeded by the Union Pacific Railway to Rawlins Springs Station, the starting-point for our journey to the field of work.

Accidents to the car carrying our supplies, and the escape of our mules from a corral, caused a delay of two days, after which we proceeded without any further mishap to the district assigned to us in Northwestern Colorado.

Hoping the following report may prove satisfactory, I have the honor to remain your obedient servant,

GUSTAVUS R. BECHLER.

DR. F. V. HAYDEN,
United States Geologist, in charge.

TOPOGRAPHICAL REPORT ON THE YAMPA RIVER DISTRICT.

CHAPTER I.

MARCH FROM RAWLINS SPRINGS TO THE WHITE RIVER AGENCY.

According to instructions the Yampa Division, consisting of the necessary assistants, as packers and a cook, and accompanied by Dr. C. A. White, geologist, proceeded on the 19th of August, 1876, from Rawlins Springs, Wyo., a station on the Union Pacific Railroad, to that portion of Northwestern Colorado which was assigned to the division for geographical exploration. This district is situated in the extreme northwestern corner of Colorado. It embraces an area of 3,000 square miles, and extends from parallel 38° 58′ fifty miles north to parallel 40° 30′, and from the White River agency, situated in longitude 107° 48′, westward to longitude 109° 30′, or 25 miles across the western boundary of Colorado.

More popularly expressed, the country may be described as lying between the White and Yampa Rivers, and between the White River Ute agency and Green River, where it is flowing in the Wonsits Valley.

The nearest and most practicable route for reaching the most eastern points of the district in order to enable us to make geodetic connections with the work of previous years, was in a southwestern direction and over the plateau country which lies between the Union Pacific Railroad and the Snake River, a distance of 80 miles by the trail which was selected. We succeeded in making the distance to Snake River in four days-marches, which, considering the usual breaking-in of the pack-animals, which for some time have been unaccustomed to the performance of disciplined work, may be considered as successful marching. For 16 miles southwest of Rawlin's Springs we had the advantage of a tolerable good road, although it led through an arid country of forbidding aspect. Its dryness and destitution of any kind of vegetation save sage and occasional bunches of grease-wood rendered it exceedingly desolate.

Leaving this region we ascended the high plateau, which towards the north and east presents bluffy faces, rising from 800 to 1,000 feet above the general level of the surrounding country. This high plateau extends to within a few miles of Snake River, but it is continuous to the westward of that river. It is one of the most fertile grass plateaus of all the West that have come under my observation. It is well watered and abounds in game, principally antelope.

The Snake River* presents a fine valley at the point of our crossing. It is a splendid clear-water stream of 75 feet in width, and from 15 to 18 inches in depth. Its velocity is considerable, and for a distance of 10 miles there are some excellent bottom-lands, together with magnificent

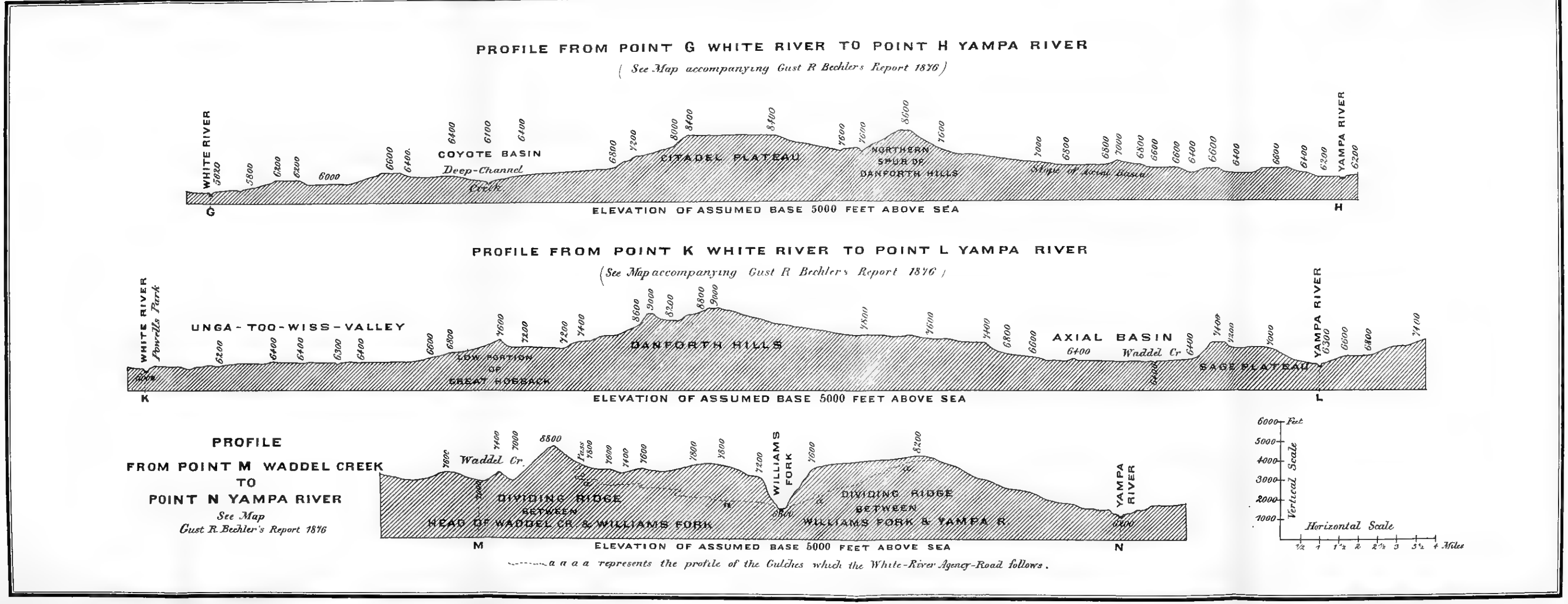
*This river ought to be called the Snake River of the East, to distinguish it from the great South Fork of the Columbia, which is also named Snake River, a name derived from the Shoshone or Snake Indians who inhabit the country near its source.

cottonwood groves. We found along this stream settlements of apparently well located and successful farmers.

Southeast from our point of crossing the Snake River, rise the Elkhead Mountains, a formidable range with numerous sharp peaks and a deeply eroded drainage system. We followed an Indian trail for 10 miles through a desolate rolling country, and then reached the government wagon-road leading to the White River agency. This road meanders around the western flank of the Elkhead Mountains. While the forest-clad mountains to our left rose with majestic grandeur, affording a highly pleasing aspect, the country to our right, on the contrary, consisted of a high-rolling, monotonous sage-prairie, with no distinct characteristics as to orographic features. The road keeps close to Fortification Creek after crossing a low divide which connects the undulating sage-plateau with the Elkhead Mountains. This creek rises in the mountains to the eastward, and contains for many miles tolerably good water, but in approaching the terraced country bordering the Yampa River on the north, the water assumes a very brackish character owing to its coming in contact with many alkaline deposits.

For many miles north of the Yampa River, the country slopes very gradually towards the river; its features are those of a monotonous wave-like plateau country, with a covering of sage as its chief vegetation. The only prominent topographical object in this region is an elevated and flat-topped butte, named Fortification Butte, which stands like a rocky island in the sage-covered waving prairie. It stands some 12 miles northwest of the point where the government road crosses the Yampa River. The Yampa River is a fine clear stream of perhaps 100 feet in width, and from 18 to 20 inches of depth in the centre of its bed. At the point of our crossing it did not possess the charming features that characterized the Snake River Valley, although there are some good patches of bottom in the numerous bends which the river makes in its meanderings through the valley.

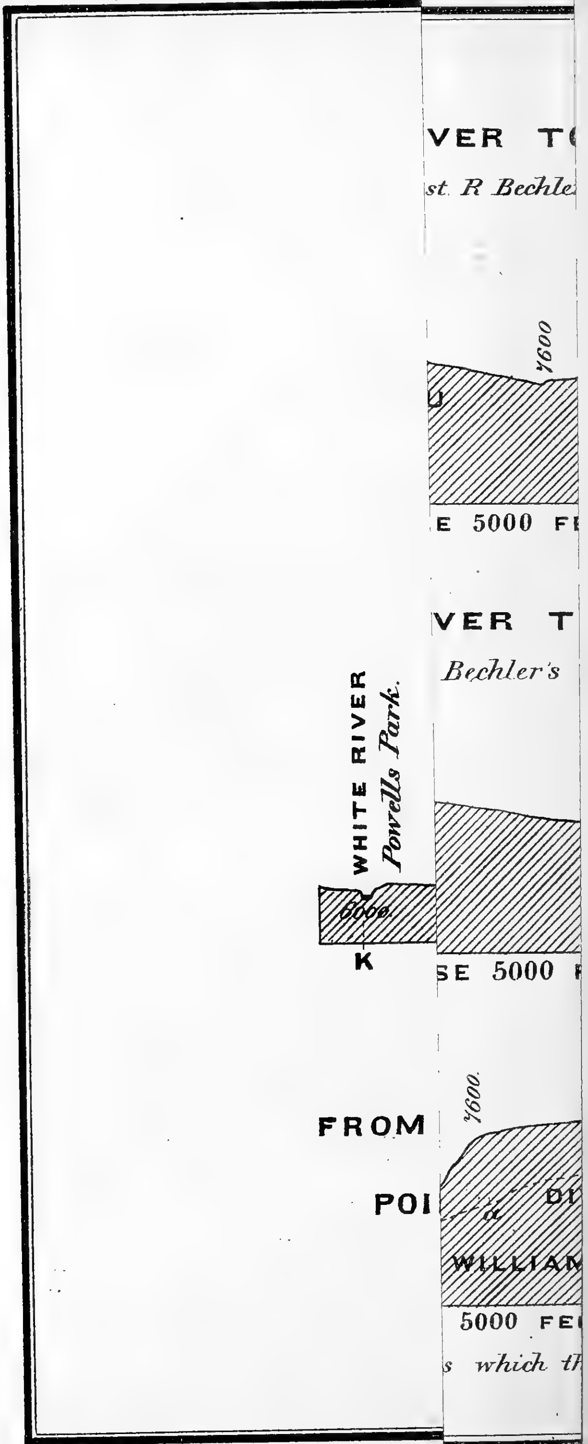
Leaving the Yampa River, the road follows through a somewhat more mountainous region toward the White River Ute agency. As this country belongs to the district allotted to us for observation, and in fact forms the eastern portion of it, the notes in describing the area will have to be somewhat fuller. While the air-line distance from the Yampa to the valley of the White River is but 38 miles, the road with its frequent deviations from a straight course makes the distance 52 miles. Within that distance the country exhibits different characters in its physiognomy. The area is diversified or broken, first by three transverse ridges, having an east and west trend, and running parallel to the Yampa River, and secondly by the cañon-valley of Williams Fork, as well as by a basin-like depression between them. The first two of these ridges are close together and separated only by the Williams Fork of the Yampa which at the point where the road crosses it, as well as for many miles on either side is in a deep cañon-like valley. The axis of the northern ridge, or the one lying between the Yampa and Williams Fork, terminates near the junction of the latter streams. The second ridge, the one lying between Williams Fork and Axial Basin, extends its axis 12 miles further to the west than does the former one. This latter portion of the ridge, which is from 12 to 13 miles long, is penetrated by two streams breaking rectangularly through the ridge, on their way to join Williams Fork and Yampa River. The eastern one of these streams is called Waddel Creek, and joins Williams Fork 5 miles to the southeast of the junction of the latter with the Yampa River. The second creek breaking through the ridge 7 miles below, or west of Waddel Creek,



a a a a represents the profile of the Gulches which the White-River Agency-Road follows.

AM. PHOTO LITHO. CO. N.Y. (OSBORNE'S PROCESS)

U S Geol. & Geogr. Survey.



is called Milk Creek, and runs directly into the Yampa River. Each of these creeks has carved a cañon in the ridge, of which the eastern one, Waddel Creek, is the broadest. From Waddel Creek westward the ridge has lost all form of a well-defined crest, and an absolute plateau form predominates. This plateau is therefore separated by Milk Creek and Waddel Creek Cañons into two distinct portions. The eastern one has been named Junction Plateau, from the fact of its close proximity to the junction of Williams Fork and Yampa River. It contains about 24 square miles of area, and the drainage arising therefrom heads close to the southern rim of the plateau and drains into the Yampa. The western plateau is tongue-like in shape, and its western extremity terminates in a sharp point, while from its being completely covered with sage the name of Sage Plateau was given to it to facilitate the description of the country and to assist in an easier comprehension of the map relating to it. The latter contains some 12 square miles of area. The first ridge, lying between Yampa River and Williams Fork, is 600 feet higher than the second one, including the Junction and Sage Plateaus.

The northern slope angle of the first ridge which occupies the area between Yampa River and Williams Fork is moderate and gentle nearly up to the brink of the ridge. This, however, refers only to the general ascent, for erosion has caused many steep gulches and ravines in that undoubtedly once very uniform slope. From the summit of this ridge almost the same level continues for four miles in a southward direction; when in close proximity to Williams Fork the ridge shows steep sides and falls off abruptly into Williams Fork Valley, thereby causing its cañon-like shape.

The evidence is clear that before the powerful action of erosion had worked upon its surface, the plateau character of this ridge was uniform. The remaining spurs show clearly the original level close to the walls which front Williams Fork. The drainage, however, descending from the plateau for ages has gashed the southern side into deep cañons, all entering Williams River Valley at right angles to the river. In one one of these deeply eroded cañon-gulches the road descends to Williams Fork.

In one respect Junction Plateau as well as Sage Plateau is analogous to the ridge or plateau just described. A gentle slope on the north side characterizes them all; their highest points resting on the southern rim, or nearly so, after which the plateaus show almost vertical faces with very little *débris* slope at their bases.

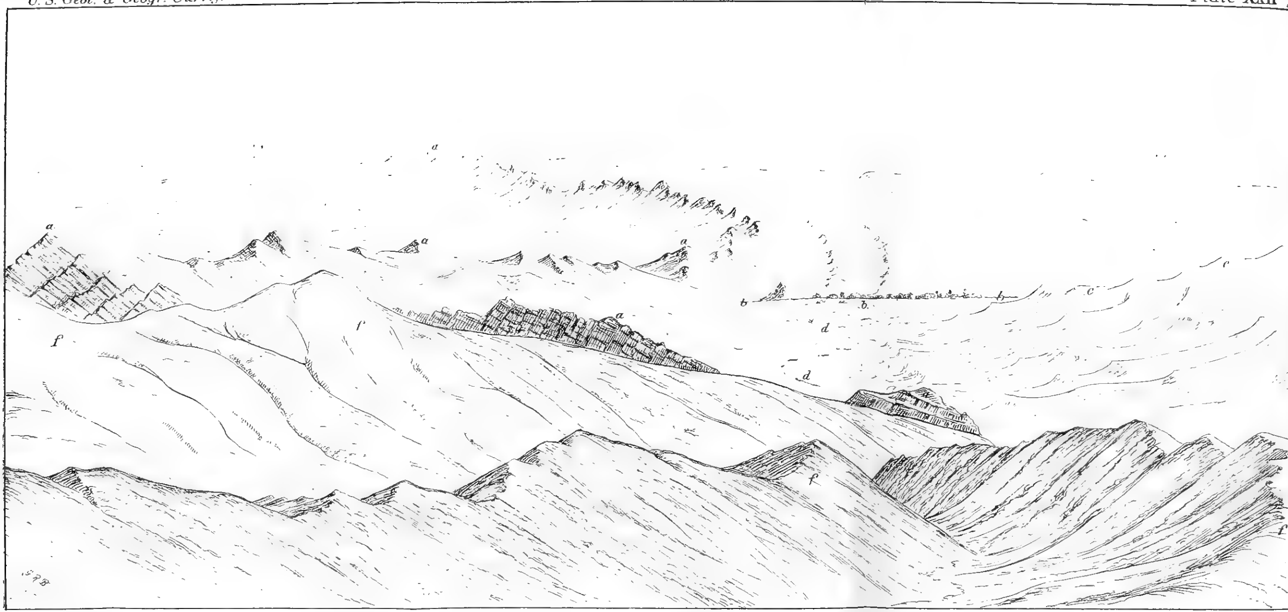
The road after leaving this cañon-valley meanders for six miles again between gently ascending hill-spurs in dales and gulches all belonging to that portion of the second ridge where the cañon form is not yet expressed, and the backbone of the ridge resembles more or less that of a regular crest of ordinary hills.

After six miles of moderate ascent we come within a few miles of the brink of this second ridge, which fronts the axial basin* on its northern side and also partly on its eastern side; while in the higher remaining portion of these hills the road has steep grades to overcome, and in dodging the numerous abrupt places its course is far from straight.

Having descended from the second ridge, we cross Waddel Creek, or at least one of its main branches, which runs close to the flank of the ridge. We traverse afterward for several miles a district of mixed topographical features, for it is not altogether devoid of the characteristics of a basin, nor is the resemblance to it of a very definite character. It has, however, the tendency to be one in future ages.

* Called thus by Dr. C. A. White to facilitate geological description.

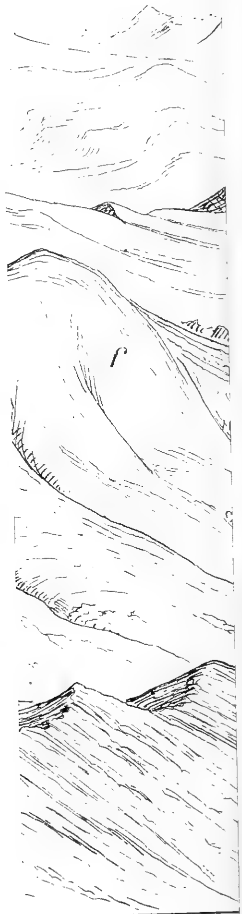
In passing on to the southwest through this gently undulating portion of the country without any boldly expressed drainage system, we pass on our right a complicated cluster of buttes sloping like all the rest of the upheavals in this region toward the north and northwest, showing also abrupt faces on the south side. Seven miles beyond we arrive at the Yellow Jacket Pass, which constitutes the lowest saddle in the third and last ridge of hills north of the White River Valley. From this pass we march for six miles through pretty rugged cañons and descend finally into the White River Valley, which we enter at Simpson's Park only some five or six miles from the White River agency house. Arriving at the latter place on August 28, after marching ten consecutive days, preparations were made to commence field-work at once, and after a few days of work geodetic connection with the survey of 1875 was satisfactorily effected. We followed, then, the usual order of working through the district assigned to us.



a a a a. Grand Hogback
b b b White River Valley (Powell's Park.)
c. c. Southern Spur of Gray Hills.

GRAND HOGBACK CROSSING THE WHITE RIVER.

d. d. Unga-too-wiss Valley.
f f f. Spurs from Danforth Hills.



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CHAPTER II.

GENERAL DESCRIPTION OF THE DISTRICT.

THE COUNTRY NORTHWEST OF AND ADJACENT TO THE WHITE RIVER AGENCY.

An area of nearly 400 square miles directly northwest of White River agency represents the more hilly portion of the district under description. The northeastern and highest portion of these hills are called Danforth Hills, and show by their structure no development of the plateau character, but, on the contrary, show a crest with many peaks, cones, and saddles, the ordinary form of mountains of the third order.*

The Grand Hogback (see Plate XXII), an upheaval of most peculiar type and geological interest, crosses the White River eight miles below the agency, and approaches and connects, by means of a saddle, with the Danforth Hills in their most southern portion.

Consistent with the general type of the whole country in this region, the northern slopes are also of comparatively moderate descent, while their southern and eastern faces are in some places extremely steep and in other places only moderately so. Their extreme height is not much over 8,800 feet. While the Danforth Hills represent only half of this hilly district, the Hogback Valley, as well as Unga-too-wiss Valley, serves as a division line between the Danforth Hills and the Western Group, where, particularly in Citadel Plateau, the mesa-like form is strongly expressed. In the Gray Hills, which form the southwestern portion of the group under consideration, mixed orographic features exist. The western wing of the Gray Hills, running in a southwestern course toward White River, shows in a great portion the plateau form, while the others indicate a waving crest, showing strongly expressed spurs and generally deeply eroded character in their totality as hills. That portion of the hills referred to is covered in places with an abundant growth of piñons.

In the whole group, Danforth Hills as well as the western portion, the drainage system is expressed in a small number of dry-washes, tributary to White River, and an equal number of drainage-beds tributary to the Yampa River are found along the northern slopes. While water may flow in all of them abundantly during the snowy part of the season, for the greater part of the year their beds are dry. In the higher portions of the Danforth Hills springs are more numerous and patches of brushwood not so scarce as elsewhere in the district between White and Yampa Rivers, but as a general rule the supply of water is more abundant near the sources of the springs than in any other part of their courses, and very often water will disappear altogether after leaving its source.

From the fact that the country in this region is totally destitute of even Indian names, we have attached many names to the creeks and

* See Report U. S. Geol. Survey for 1875, p. 372.

drainage-basins, which divide the country, more or less, into different zones, and also to ridges, plateaus, which, notwithstanding the minutest description, would, without names, be unrecognizable on reference to the map.

Unga-too-wiss Valley, which opens in a basin called Powell's Park, near White River, is only 12 miles west of the Ute agency. It heads from 15 to 16 miles north of Powell's Park near the divide which connects the Danforth Hills with Gray Hills. North of that divide lies a basin called Hogback Valley which forms the head of Deep Channel Creek, which, in its general westward course, flows through Coyote Basin before it enters the White River, 20 miles northwest of Powell's Park.

There is a spring to be found at the head of Unga-too-wiss, and another one in Hogback Valley. Deep Channel Creek keeps and even accumulates a little water in its course to its junction with the White River, while Unga-too-wiss Creek for 12 miles from its source shows no sign of water. The hills that surround these valleys are a true type of the whole country adjacent to the region. Their appearance is desolate and forbidding, while the valleys are still less inviting. The facilities for marching through this country are few on account of obstructions of diversified kinds; the chief ones are the dry-washes, or gullies of a small cañon order, the interminable sage, and the prickly-pears; the latter cover the ground for miles.

Unga-too-wiss and Coyote Basin, are literally cut up by gullies from 6 to 30 feet, and even as much as 60 feet deep; frequently they are hidden by sage so as to be completely invisible until we reach them. Occasionally we arrive at a spot where a dense growth of large sage, not easy to penetrate, covers the ground.

YAMPA AND WHITE RIVER DIVIDE.

The main divide between White and Yampa Rivers is along the crest of the Danforth Hills. It approaches nearest to the White River Valley at Yellow Jacket Pass, where it is but nine miles distant from it. Its winding course, thence along the summit of the Danforth Hills, is northwest until it reaches a point a few miles north of Citadel Plateau, when it is again but nine miles distant from the Yampa River.

At the head of Coyote Basin a series of sharp cones, the highest of which is not over 7,800 feet above the ocean, are the last seen on the summit.

In an almost straight western course, and with only a slight deviation to the south and in still closer proximity to Yampa River, the crest runs for 15 miles, from Wampita Peak to the head of Vale Disappointment, which lies on the Yampa side, while Midland Basin is on the opposite, or White River side. At this point there occurs a sharp turn to the northward which holds for several miles, and thereby brings this divide within six miles of the Yampa River. It afterward continues in a succession of high bluffs in very close proximity to the cañon. These bluffs constitute the northern rim of the Great Yampa Plateau, in whose broad expanse a definite crest is finally lost.

The only side ridge, showing all the elements and general conditions of an independent hill-cluster and which detaches itself from the main divide and runs toward the White River, is Piñon Ridge, a rugged and singularly eroded upheaval, presenting the usual gentle hill-slope on the east side, while on the opposite or west side the most strangely eroded flanks characterize them. Piñon Ridge forms also a dividing

line between two rather large basin-like depressions—Coyote Basin on the east and Midland Basin on the west. Through both of them we find long, waving parallel lines of hogbacks with a general north and south trend, which appear above the surface in a labyrinth of crests, resembling a ploughed surface where the furrows have been upturned by some gigantic plough. The drainage channels descending from the main divide as well as from Piñon Ridge into these basins are numerous, but, consistent with the general nature of the country, they are all dry.

THE WHITE RIVER VALLEY.

If we apply the name of valley to the whole of the White River during its flow through this district, it is simply used as a conventional term, for all rivers flowing in plateau countries possess only in part the features of a real valley.

The scene changes in a plateau country according to the arrangement of ridges into bluffs or benches, from valley to cañon or cañon-valley, and *vice versa*. The general course of the river after leaving White River Ute agency is westward like that of the Yampa River, notwithstanding the fact that great bends often cause it to deviate for many miles to the northwest or to the southwest as the case may be. Such a bend or a large sweep to the northwest occurs 16 miles west of the agency, from which point the course of the stream is for 20 miles due northwest, after which it shows for 14 miles a gentle tendency south from west, when, after a sudden short bend directly south, breaking through a plateau ridge, the stream assumes a southwestern direction until a point some 20 miles west of the Colorado boundary is reached, when the course is again changed to the northwest.

The physiognomy of the country is different on each side of the White River; on the south side, high and massive plateaus, with their summits 30 miles from the river, characterize the country, while the country along the right bank and as far north as the Yampa River is, with a few exceptional portions, dismembered and chopped by detailed drainage, as would be expected in a plateau country of soft material subjected for ages and ages to erosive influences.

With the exception of the Danforth Hills, a group of some solidity and compactness, there is but one really extensive as well as massive structure between White and Yampa Rivers; this is the great Yampa Plateau, to which we will allude in more detail hereafter.

The drainage itself that enters the White River on either side indicates a totally different arrangement and character of the country it comes from. On the south side, for instance, we find four large streams with an abundant supply of water entering the White River between the agency and west line of Colorado, while on the north side, within the same distance, we have no stream whatever supplying the White River with additional water, if we except the insignificant brook which, coming through Coyote Basin, contributes to the White River an amount of water equal to that of a small meadow-brook.

If we proceed from the agency down the White River as far as the boundary line separating Colorado from Utah, a distance of 85 miles, we pass on our journey through four basin-like spots, where the drainage accumulated in the plateaus north during the winter season comes forth to swell the White River. These basins are deceptive in regard to water for the greater portion of the year, and delusive as to their real character until we approach and are really in them, when we find they have no real bottom area. Their surface is uneven, dry, and barren,

broken by cañon-like fissures which the main as well as intersecting streams have carved.

The most valuable bottom or basin area existing on the White River is that of Simpson's Park, near the agency, and this area without irrigation applied would be reduced by obstacles of diversified character, perhaps, to but two or three square miles of land fit for agricultural purposes.

The basin next largest in size to Simpson's Park is about 10 miles down the river, and to it the name of Powell's Park has been given. As it is far less extensive than the Agency Park, and, except a small strip along the river, lacks many conditions necessary to render it useful, little value is attached to it.

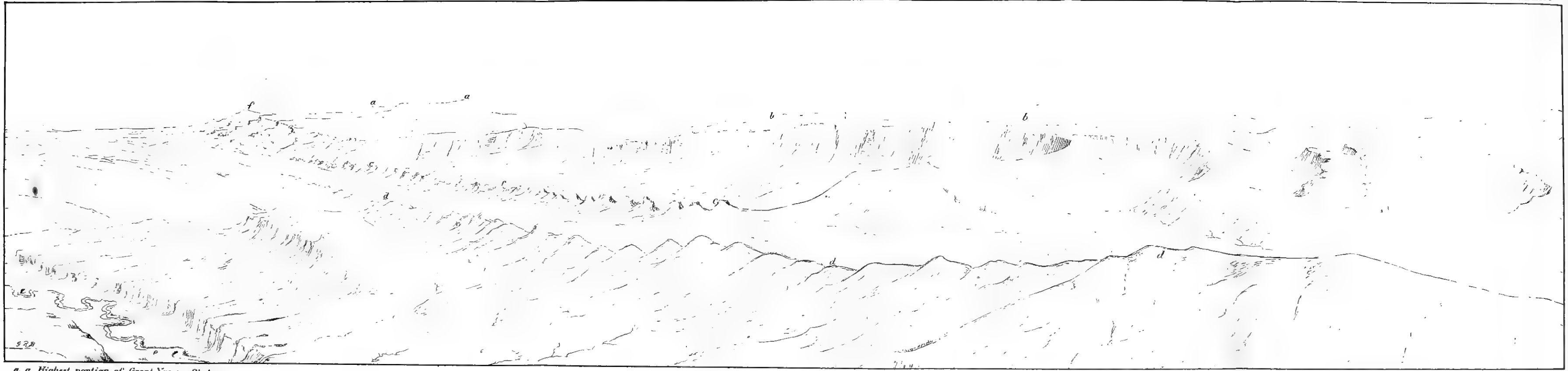
In travelling beyond Powell's Park and down the stream, we pass two more basin areas of lesser extent. In this region, as well as in many places farther down, the stream frequently impinges on the bluffs on both sides, making travelling toilsome, as frequent crossings become necessary. Very often the banks are abrupt and had to be cut in order to effect a crossing or to enable us to reach water for our animals and ourselves.

The general appearance of the country along the White River is of the most desolate character; there are but few, if any, redeeming features in it. There are few places along White River that are not lined with bluffs, terraces, or high banks, most of the time approaching the river margin very closely, and only where the plateau shows a basin do the embankments or bluffs recede to the rear.

The nearer the White River approaches the Colorado and Utah line, the higher the plateau rises above the river. When 16 miles east of the point where the river leaves Colorado it reaches about the meridian of the most eastern portion of the Great Yampa Plateau, which about 15 miles to the north rises above the lower mesa like huge walls of gigantic fortifications. Along the whole front of the Great Yampa Plateau, the lower mesa, coming close to the river, is higher than elsewhere. In Raven Park as well as in its surroundings (referring to the lateral cañons that enter Ravens Park above) we have a clear demonstration of the powerful and at the same time curious effect of water operating on a flat area, in the wearing down and gashing, as in this case, of a district of, perhaps, 40 square miles. There are left the strangely moulded remnants of a former level surface.

A few miles below Ravens Park White River enters a cañon caused by an additional covering of stratified rocks. The general height of the cañon at a point about 7 miles west of the Colorado and Utah boundary was found to be from 1,200 to 1,500 feet, but there is no doubt that as the river descends in its course toward Green River, the cañon walls may attain a height greater than 2,000 feet.

It will be necessary here to describe only briefly the country across and north from the White River extending toward the Yampa River as well as to the western extremities of the Yampa Plateau. In referring to this portion of the area I have to mention that, like the eastern half of the Yampa Plateau, it belongs politically nearly in its totality, to Utah Territory. It bears all the characteristics of bad lands, a term used very often in the descriptions of Western countries, where aridity, sterility, and sparseness of vegetation prevail. The highest portion of this plateau country is a strongly expressed line of hogbacks, running diagonally from the point near the White River, west of Ravens Park, to the high and conspicuous bluffs that form the extreme southwestern walls of the Great Yampa Plateau. The distance across is 24



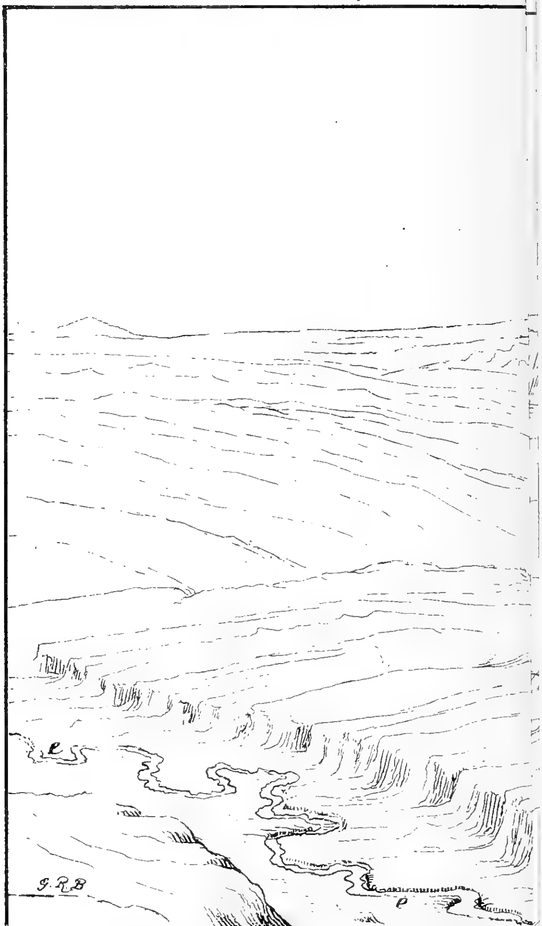
a. a. Highest portion of Great Yampa Plateau.
b. b Eastern portion of Great Yampa Plateau (Midland Ridge)
f Split Mountain 44 miles off.

THE GREAT YAMPA PLATEAU.

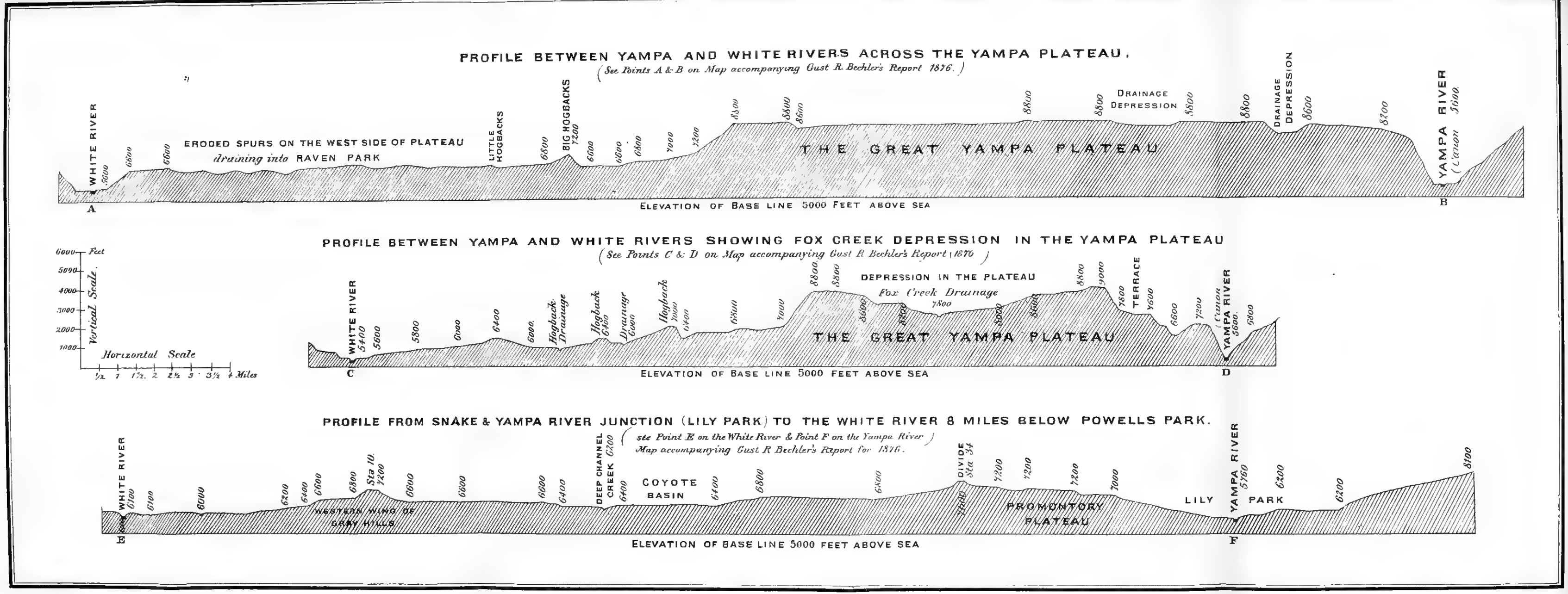
c. c. c. Hogback Ridge fronting the Plateau
d. d. d. Hogback Ridge along White River
e. e. White River Valley.

AM. PHOTO LITHO CO. N.Y. (OSBORNE'S PROCESS)

U. S. Geol. & Geogr. Survey.



a. a. Highest portion of Great Yampa Pla
b. b. Eastern portion of Great Yampa
f. Split Mountain 44 miles off.



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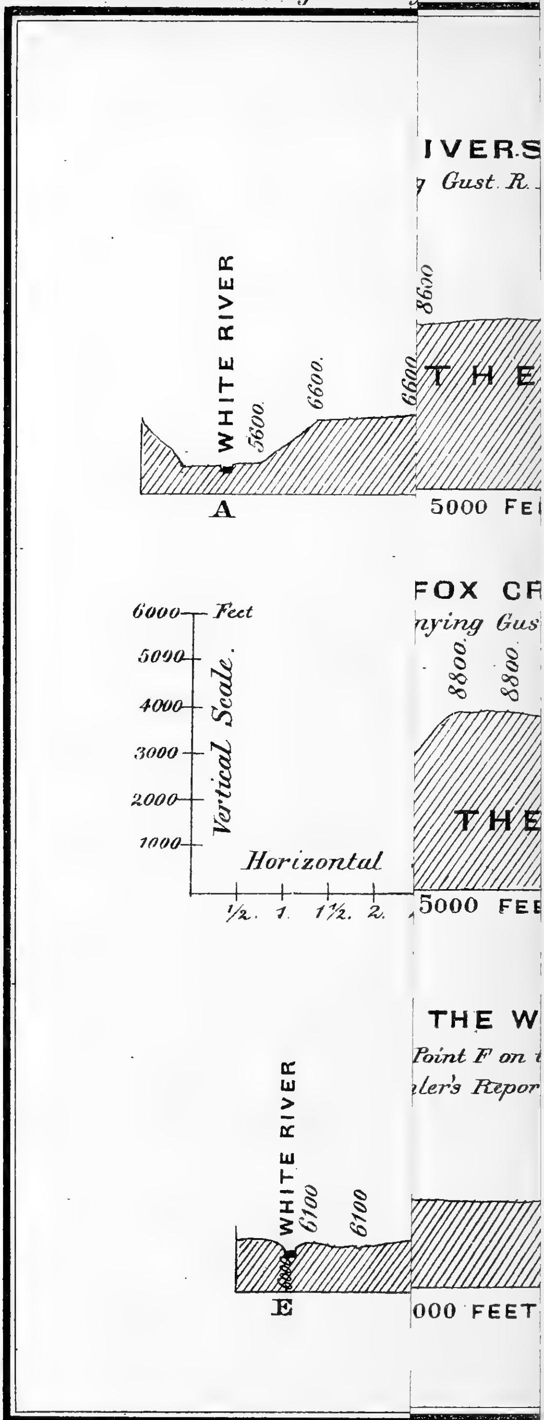


miles and the average height of the line of hogbacks is from 7,000 to 7,200 feet elevation.

Beginning at the crest of the hogbacks the descent is westward toward the Green River, where the latter is flowing in Wonsits Valley. The general surface is slightly undulating, with here and there pulpit-like exposures rising above the surrounding level. While cactus represents for miles the only vegetation, sage is mingled with it in the highest and flatest portion of the plateau.

We become tired and weary with the monotonous sight of naked hills, terraces, prickly-pears, and sage. If the variety of color in the strata along the hillsides or exposed in banks and terraces gives often a pleasant warm tint and produces an admirable picturesque effect, it can never altogether compensate us for the total absence of forest vegetation and grass, without which there is but little charm in a landscape.

THE GREAT YAMPA PLATEAU.

The most interesting upheaval or orographic structure in the western portion of the district between White and Yampa Rivers is the Great Yampa Plateau, a high table-land which, comprising between 300 and 350 square miles of area, exhibits very abrupt faces around nearly its whole circumference. The surface of the plateau is undulating and better adapted for grazing purposes than any other part of the entire district.

On the eastern half of the Plateau along Fox Creek springs and even running water may be found. Along the northern lines of bluffs which front Yampa River, the plateau is higher than elsewhere. The height is about 3,600 feet above the Yampa and Green River Junction, while the total elevation above sea-level is 9,000 feet. In this area there is only one point, viz, Tank Peak; it attains a height of 9,200 feet and is situated in longitude 108° 45′ and about four miles south of Yampa River.

The southwestern part of the plateau contains the most level surface and is about 200 feet lower than the northern portion. Its average altitude is 8,800 feet. The surface on this side of the plateau is covered with occasional patches of brushwood. Along the *débris*—slopes and spurs and beneath the most abrupt sides which the plateau presents, dwarf pines and piñons are found in abundance.

There is some drainage starting along the bluffs, but the principal drainage arising on the plateau seeks an outlet chiefly to the north and east. The creeks having a tendency to flow northward break through the strata and rapidly descend through narrow defiles to their mouths in the Yampa River.

The eastward-flowing streams which unite in the channel of Fox Creek, have produced a deep concavity in the centre of the eastern half of the plateau. (See profiles of the Great Yampa Plateau.) In this basin we find not only splendid grass, but also good water sufficient for all ordinary purposes. The soil, however, absorbs the running water before it reaches the lower end of the basin. The plateau can be ascended only from two sides unless we are light-footed and good climbers. The depression which Fox Creek has cut in the plateau affords the easiest means for ascending it. With some greater difficulty the plateau can be ascended on the west side along the slope which descends toward Cub Creek.

The plateau region abounds in game, though we had not the good fortune to be benefited thereby. The western rim of the plateau faces Green River and Split Mountain, where Green River Cañon terminates

and the stream is freed from its rocky inclosure. The distant view obtained from here is magnificent. We are not only interested in the great gorge from which the Green River emerges into the broad expanse of a valley, but we can also trace the stream in its winding course far to the south, and have a fine view in the northwest, the Uintah Mountains, with their lofty snow-covered peaks, presenting a spectacle rarely equalled.

In describing the features of an almost totally unknown country, it is necessary to give greater detail than the country would sometimes seem to deserve, inasmuch as its value, practical or otherwise, must be determined. We would, therefore, be in error were we to omit allusion to a peculiar and interesting feature connected with the great Yampa Plateau. This feature is a well-defined, regular line of hogback hills which, about three miles north of the northern plateau rim, stretch like a wall around the great plateau (see Plate XXIII,) cut only here and there by the drainage which has its source between the hogback hills and the plateau itself.

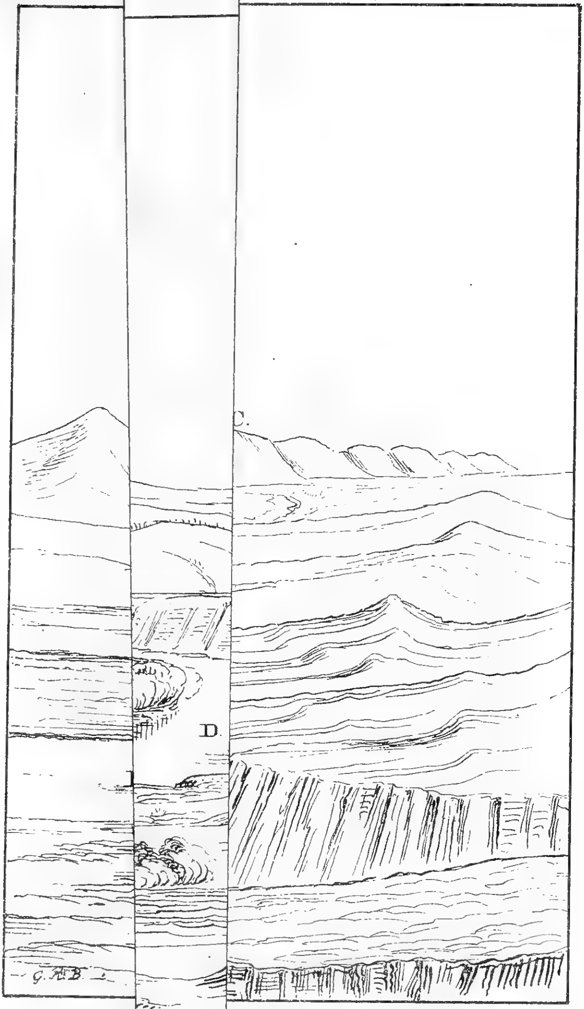
From the connection that can be traced between the highest portion of Midland ridge and the hogback hills, it seems evident that from the hogbacks which present now steep faces towards the equally eroded faces of the great plateau there once existed between them a continuous surface which has been eaten away by erosion, leaving it with its present shape. Submitting all theories on the subject to the geologist for discussion, I will simply mention its present topographical appearance.

The wall-like barrier with which the hogback hills, in a curved line, circumscribe the plateau from Weary-mules-wash to within a few miles of the western end of the plateau is singularly striking in appearance. The hogbacks are really inclosures of a series of more or less well-expressed mountain basins, which lie along the *débris* slopes and spurs of the great Yampa Plateau. The hogbacks are also frequently broken by washes through which the drainage during winter and spring time finds its way out of the basins.

The largest of the amphitheatres produced by the eccentricities of erosion lies directly north of Midland ridge (see Plate XXIII,) which is only the eastern although somewhat lower portion of the Yampa Plateau itself. This basin is thoroughly amphitheatrical in shape and is perhaps 10 miles long, from east to west, and 3 miles in width. A gentle but very even rocky slope, with deeply cut drainage fissures in it, descends from the *débris* of the plateau walls to the foot of the hogback hills. The exposed faces of the plateau as well as those of the hogbacks consist of red sandstone, and in consequence of this the brick-colored faces of these exposures contrast strangely with the gray and dull color of the surrounding scenery.

YAMPA RIVER.

This stream excels its sister stream the White River, not only in its scenery, but also as to its pasturage and quality of such agricultural area as under the most favorable circumstances this sterile plateau country affords. Latitude 40° 30′ forms the line along which, with repeated crossing and recrossing, the Yampa River flows for 80 miles to the westward. The stream indeed shows a direct westward tendency from the very point where it first assumes the importance of a river, which is in longitude 107°; thence flowing westward to its junction with the Green River, which is 1½ miles west of meridian 109°. Its total length from latitude 107° to the Green River, is about 100 miles in



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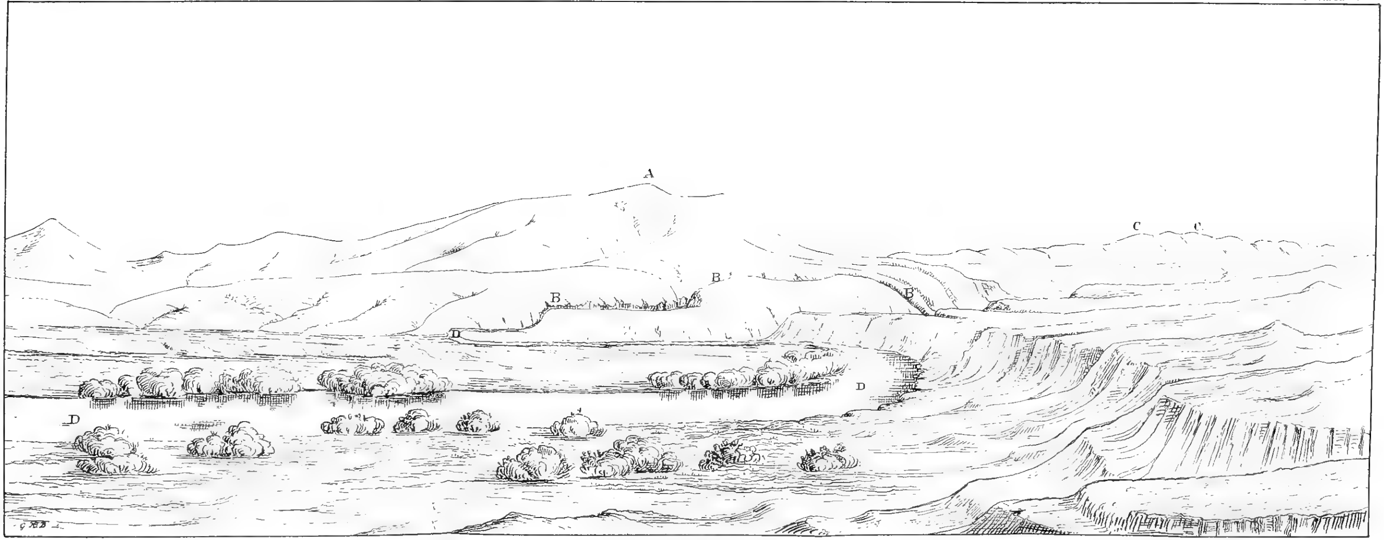

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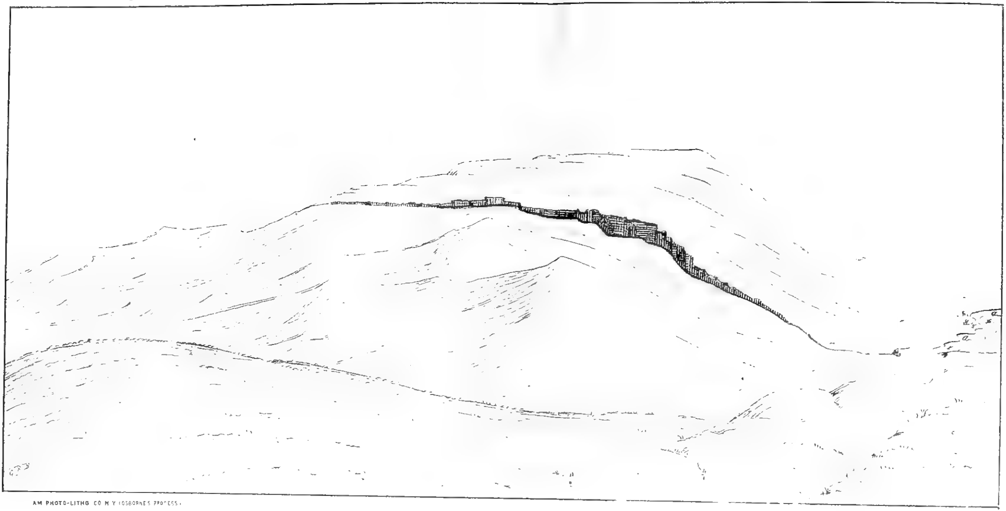
VIEW ON THE YAMPA RIVER

A *Yampa Peak*. B B B. *small Cañon* C. C. *Junction Mountain*. D. D D. *Yampa River*.



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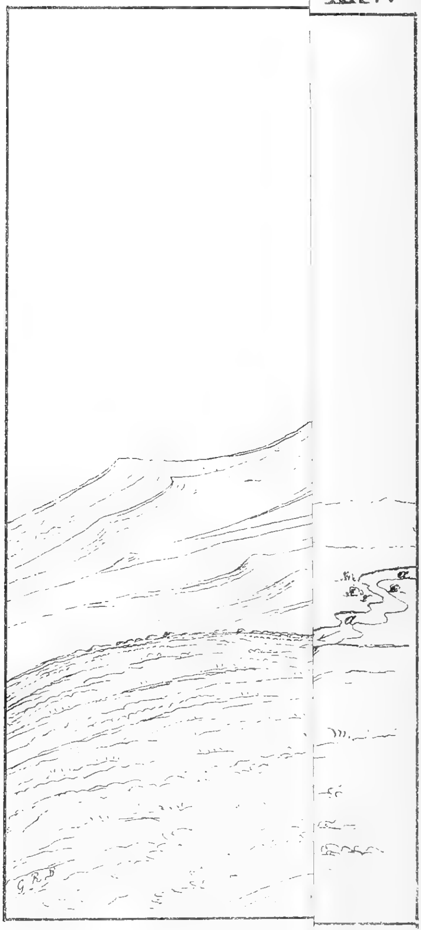
YAMPA RIVER CAÑON
through Junction Mountain.

a. a. Yampa River.



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PR

River.

a straight line. Repeated changes in its features are characteristic of this stream. Basins, cañons, and cañon-valleys, with occasional spots of well developed valley, constitute its main features. The valley form is, for instance, decidedly expressed for 24 miles along that portion of the river which terminates with the junction of Williams Fork, from which point the stream flows for 10 miles, more or less, in a cañon, which contains not only some picturesque scenery, but in the river-bends occasional small park areas. By repeated crossing we are enabled to make our way with pack and saddle animals through this half cañon of the Yampa. The river emerges from this semi-cañon at the western terminus of Sage Plateau, which is elsewhere described in these notes. The river enters here a splendid bottom of five or six miles in extent, leaving which, it forces a passage through a small cañon situated near Yampa Peak, in longitude 108°. (See Plate XXIV.) After passing this cañon the stream meanders for 16 miles in a basin-shaped area, having the name of West-axial Basin on the accompanying map. While in this basin, the river flows on the north side near a girdle of not very high but abruptly-rising bluffs.

West-axial Basin constitutes principally a gently descending area of terraces, covering from 50 to 60 square miles, which lie on the north side of Citadel Plateau and Wampita Peak.

A splendid patch of river bottom with rich grass distinguishes from the remainder of the basin the lower or western end of the valley immediately below Junction Mountain. There, where the most western margin of this grassy bottom meets Junction Mountain, there opens a tremendous gorge with almost vertical walls of about 1,000 feet in height, in which the river disappears (see Plate XXV,) but only to emerge again 2 miles beyond in a pretty little valley named Lily's Park. Here the Snake River joins the Yampa, and rich grass and cottonwood groves characterize this, which is, perhaps, the finest valley in the course of Yampa River (see Plate XXVI). This park is surrounded on all sides by eroded terraces and plateau spurs which rise step by step to the divide on either side. Promontory Plateau rises on the south side just opposite the junction of Snake and Yampa River, to a height of over 1,000 feet above river-level, while Junction Mountain attains an altitude of 1,800 feet above Lily's Park, or 7,800 feet above sea-level.

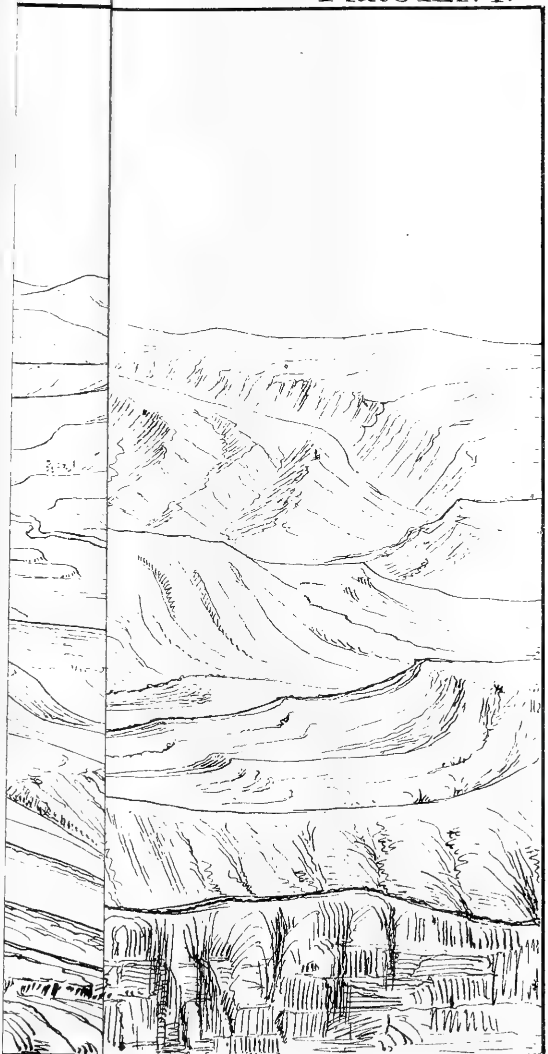
The best portion of this small area of Lily's Park lies on the south side of the river, and at a point where Vale Disappointment—a small, dry valley—approaches Lily's Park the Yampa River again enters a huge fissure in the mountains. In this it remains with great persistency during nearly its entire course down to i s junction with the Green River.

From Lily's Park to Green River Junction, a distance of 26 miles in air-line, the Yampa flows within narrow, precipitous walls, and only when within a distance from 6 or 8 miles from Green River does it come out of the cañon, touching the margin of a basin (Red Rock Basin) which lies along the northern slope of the Great Yampa Plateau. It, however, suddenly disappears again, as if showing a decided preference for a dark, rocky inclosure rather than for freedom. There is no doubt that this piece of drainage of the Yampa River between Lily's Park and Green River Junction is one of the most remarkable on record. All along this portion of the river, and only from 1 to 2 miles south of it, lies a basin-like depression, to all appearances just molded for a valley, and, as far as can be discovered by ordinary observation, seeming to be nothing else else but the actual synclinal axis between the strata dipping from the Yampa Plateau and those dipping from the opposite Escalante Hills. In consequence of this it would seem to be the proper course for the river,

but instead of choosing the latter and apparently easier course, it penetrates the rocky strata of Escalante Hills with persistency, leaving untouched the basin which lies but a very short distance from the river. It can hardly be otherwise but that the present river channel is antecedent to the surrounding uplifts or structure, and that the basin alluded to has been caused by erosion of comparatively more recent date. The latter question, however, pertains more to the duty of the geologist, who in this case has no doubt arrived at a similar conclusion.

Near the junction of the Yampa and the Green River lies a small park-area, named Echo Park in previous explorations of this river by Major Powell and leaving this park the stream, now called Green River, soon enters a precipitous cañon and remains in it for 8 miles, passing afterward through Island Park in large curves, after which it is again buried between the huge cañon cliffs of Split Mountain, within which the stream remains for 5 miles before it emerges, at last, into the Wonsits Valley. The height of the cañon walls along Yampa River vary from 1,000 to 1,500 feet, and those of the Green River from 2,000 to 2,500 feet.

Plate XXVI.



Snake & Yampa Rivers.

PA Fer.

27 miles off.

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a a. Juntion Mountain.
b b Yampa Cañon through Junction Mountain.
c. c Promontory Plateau.

VIEW OF LILY PARK ON THE YAMPA RIVER.

d Junction of Snake & Yampa Rivers.
e Yampa River.
f Yampa Peak 27 miles off.

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CHAPTER III.

CLIMATIC AND ECONOMIC NOTES.

The climate is extremely dry, and this fact is in itself sufficient to explain the absence of a luxuriant vegetation. There is no doubt that with irrigation some localities, as, for instance, small strips along the river bottoms, could be improved and made useful for agricultural purposes, but the vegetation-bearing area would be small, indeed, in proportion to the vast mass of country that lies between the White and Yampa rivers. As by any statement in regard to percentage of agricultural land grave errors would be unavoidable, unless this subject was made the point of a special and thorough investigation, we will abstain from giving positive figures relating to the proportion of good and bad land. We will venture to say, however, that the encouragement held out to a limited number of settlers is greater on the Yampa than on the White River, as there are a number of small parks in which there are considerable areas of more than usually good bottom-land. Excepting Simpson's or Agency Park, which contains a comparatively large area of good land, only in few cases and but for short distances does the alluvial bottom of the White River attain a width of even a mile. The places in which the bottom along the White River opens to the width of about a mile are not numerous, as they occur only in three places in a distance of 80 miles westward from the White River agency. For the greater part the river flows either in cañon or in narrow defiles, crowded by broken terraces and benches, with an occasional narrow patch that might be cultivated by means of irrigation.

From the junction of Elkhead Creek with the Yampa River down to the junction of Williams Fork the conditions for pasturing are tolerably good, and besides the actual bottom area, several thousands of acres—now terrace land—might be made useful through irrigation. The Yampa flows from Williams Fork junction, as before stated, in a semi-cañon, exhibiting only here and there a few acres of ground that might be made useful. This is followed by a comparatively small but rich bottom between Sage Plateau and Yampa Peak. In extent this bottom or valley is 6 miles long, and in its upper portion nearly a mile in width. In the lower portion of the valley, nearer Yampa Peak, its width lessens to $\frac{3}{4}$ and even to $\frac{1}{2}$ of a mile. Abruptly rising bluffs with deep cut gulches form its northern margin, while the generally gradual rising but very undulating benches of axial basin present also occasional but inferior bluffs on the south side of this little valley.

Between Yampa Peak and Junction Mountain the terraces of West-axial Basin approach the river very closely, and, as a consequence, the bottom area is small. If water could be conveyed by means of ditches around Yampa Peak in the rear of West-axial Basin, a comparatively large area could be subjected to cultivation, but hundreds of terraces and benches, broken by large and small ravines, as well as by deep mountain gulches, that descend from Yampa Peak, would make the task a difficult one.

The fourth patch is found near the junction of Yampa and Snake Rivers, and is called Lily's Park. This park-valley is not very extensive; it is not quite 5 miles in length, and is from ½ to 1 mile in width. It is surrounded by the abruptly-rising spurs and benches of Promontary Plateau and Junction Mountain, as well as by those that run out from the high hills to the north of the park. This park represents the last spot of agricultural land on the Yampa River, and together with a portion of the Snake River Valley might give accommodations to a few settlers.

For the remainder of its course, down to where the Green River finally absorbs its name, the Yampa flows, as already described, in an almost vertical cañon, wherein naturally even the smallest area of useful land does not exist.

The defile in which Williams Fork of the Yampa meanders can scarcely be called a valley—it would be a misnomer, and, indeed, few are the acres that could be found in it to be regarded as farming land.

All over the Western Plateau region the same unfavorable conditions prevail even to a greater degree than here, for we have in the district already noted at least two prominent streams on which we would find the necessary water to accomplish the irrigation which would be possible along their banks.

Although this plateau region may be classed among the driest, it is not absolutely destitute of rain; only the regular periodical rains common in all moderate climates are wanting. The occasional rains that fall are short in duration, but violent in action. Moderation in climatical phenomena, we might say, does not exist throughout the far West, and that it has been the case for ages is proved by the absence of a sod, or a mantle of deep-rooted grass-vegetation. The rain-fall that occurred several times during our sojourn in this region was violent in the extreme but short in duration. The total absence of a well-connected sod permitted the water to run off suddenly, as if poured on a crust of terra cotta. Every trace of moisture disappeared almost in as short a time as the rain lasted. The nature of the ground is unfavorable for the gradual absorption of the moisture, nor did we observe moderation in the accompanying elements during or after the rain-fall. The rain was generally accompanied by a very low temperature, so much so, that hail and snow were generally associated with the rain. After the cessation of rain followed either a piercing cold wind or an extreme heat, which caused the recently-moist clay-ground to crack or break into wrinkles. The water flows off rapidly, gathers in its natural drainage-channels, through which it ploughs and digs deeper and deeper into the soft material, each creek, large or small, producing thereby a perpendicular deep fissure or small cañon, which have been seen in places as much as 60 feet deep, with only a width of perhaps 20 feet from rim to rim.

Under the existing conditions we may arrive at the conclusion that this plateau region cannot be made available for agricultural purposes, and there is hardly a doubt that even the most desperate attempts of an over-populated but industrious community would fail in the attempt to change this country for the better.

Through ages this plateau region seems to have possessed this dry character during the greater number of months in the year; the topography as well as the vegetation bears testimony to this fact.

There exists no gentle undulating ground anywhere except on the very tops of the plateaus. The whole surface of the crust indicates the violence of erosion during winter and a desert-like dryness during the

summer. The water which flows in deeply cut river channels, such as Yampa and White River, is not accumulated in this locality, at least not the hundredth part of it, as it comes from the distant snowy amphitheatres of the Rocky Mountains, and in its long course to this arid region has not gained in volume, but, on the contrary, has lost largely both by evaporation and sinking.

CHAPTER IV.

NOTES ON TRIANGULATIONS AND MEASUREMENTS OF HEIGHTS.

Parallel 40° 30′ forms the most northern line of the area surveyed in Colorado, by Dr. F. V. Hayden's United States Geological and Geographical Survey of the Territories, during the years 1873–1876, while parallel 40° 15′ is the southern line of the work performed by Clarence King's Survey of the Fortieth Parallel, during the years of 1867–1872.

A net-work of triangles was expanded over the respective districts of the two separate surveys in the usual manner, in each case from carefully measured base-lines. The base-lines of Clarence King were situated near Fort Steele and Sherman Station, on the Union Pacific Railroad, while those of Dr. Hayden's United States Geological and Geographical Survey were measured near Denver, Col., and in the San Luis Park.

It might reasonably be presumed that in the expansion of primary as well as secondary triangles, from bases several hundred miles apart, with only natural objects used as sighting-points, the accumulation of error would be exceedingly large at those portions of the area the most distant from the base lines, and in the plateau country where good sighting points become scarce would necessitate a large correction.

It is evident that the most practical test of the accumulation or non-accumulation of error would be the comparison of points determined by Professor Hayden's United States Geological and Geographical Survey, with the same points determined by the geodetic corps of Clarence King's Survey of the Fortieth Parallel during the years 1867–1872.

With no little satisfaction we are able to state that between the two surveys starting from different base-lines the coincidence of points is remarkably close; so close, indeed, that on the scale adopted by us for the publication of maps the difference is scarcely apparent.

Being supplied with all the maps bearing the stamps of official publication—with a view of comparing data—we found, as far as comparisons of trigonometric work were concerned, that the location of points from the Survey of the Fortieth Parallel alone were trustworthy, while the errors of other published maps of that country were great and completely at variance with the true relations and conditions of the surface.

In the latter part of the year 1874 a barometric station was established at the White River Indian agency by Mr. A. R. Marvine's division of Dr. Hayden's United States Geological and Geographical Surveys of the Territories, at which tri-daily observations were continued up to the time our party left the district in the fall of 1876. On this base depend our observations for altitudes throughout the district lying between the Yampa and the White River.

It is but fair to state that these heights cannot be considered irrefu-

table or absolute, although they come undoubtedly a great deal nearer truth than any determinations of heights made by previous surveys in this region or others adjacent to it, as their respective base barometers were too distant, and recently discovered discrepancies in railroad levels made corrections necessary which changed the results over 100 feet from previously assumed elevations throughout the Rocky Mountain region.

Notwithstanding the more generally correct determinations of altitudes of many points and places all over the region within the Rocky Mountain system, the difficulty of obtaining absolutely correct elevations is not removed when the time for field observation is but short, the temperature and climate being variable during that short period.

Our results of elevation are partially derived from observations with the cistern barometer and partially from corrected aneroid readings, while vertical angles have also assisted in the determination of the general heights of this country. These, at least, for all practicable purposes, are satisfactory, while to obtain real scientific accuracy in the results would require a much longer time of observation.

In conclusion, I wish simply to add, that in the survey of our district we followed that method of work which has been uniformly adopted by the various field parties of the survey for several previous years.

Within this district stations were made on thirty-five of the highest points, and observations for both geodetic and topographic purposes were made thereon, while six auxiliary stations were made to supplement the work in necessary places.

Approximate geographical positions and elevations of prominent points between Yampa and White River, and from meridian 107° 23′ 0″ *to* 109° 15′ 0″.

Names of located points.	Longitude.			Latitude.			Elevation in feet.
STATIONS ON MOUNTAINS OR POINTS ON PLATEAUS.	°	′	″	°	′	″	
Station II, Danforth Hills	107	47	28	40	5	27	8,450
Station III, Danforth Hills	107	48	8	40	9	55	8,644
Station IV, Danforth Hills	107	52	0	40	9	47	8,960
Station V, Danforth Hills	107	53	4	40	10	48	8,975
Station VI, Danforth Hills	107	57	45	40	12	36	8,950
Station VII, Danforth Hills	108	0	0	40	14	25	8,820
Station VIII, highest point on Gray Hills	108	5	30	40	13	55	8,830
Highest Point on Grand Hogback	107	9	28	40	7	30	8,600
Escarpment Peak, Citadel Plateau	108	6	30	40	17	15	8,820
Station IX, Danforth Hills, east of Escarpment Peak	108	4	45	40	19	0	8,815
Station X, western wing of Gray Hills	108	12	47	40	9	38	7,250
Twin Points { Eastern one	108	8	45	40	11	0	8,400
Twin Points { Western one	108	9	50	40	10	45	8,400
Station XVI, or Yampa Peak	108	0	46	40	26	30	8,220
Average height of highest points on Piñon Ridge	(*)			(*)			7,400
Station XXV, Wampita Peak, Yampa divide	108	15	43	40	22	4	7,951
Station XXIII, Yampa divide	108	21	3	40	21	30	7,600
Junction Mountain, near Snake and Yampa River Junction	108	22	0	40	30	0	7,800
Promontory Plateau, highest point, south of Lily's Park	108	22	0	40	23	35	7,200
Station XX, east point of Midland Ridge	108	42	32	40	19	18	8,750
Station XIV, highest point Yampa Plateau	108	50	40	40	18	28	8,900
Station XV, six miles east of Raven's Park	108	43	15	40	7	8	6,650
Station XVII, Lower Plateau above White River Cañon	109	11	0	39	59	25	6,400
Station XVIII, southwest rim of Yampa Plateau	109	9	13	40	20	15	8,820
Station XIX, Buena-vista Peak, Yampa Plateau	108	54	0	40	26	0	9,150
Station XXI, Tank Peak, Yampa Plateau	108	44	50	40	25	0	9,200
Station XXVII, near small cañon below Yampa Peak	107	58	50	40	28	0	6,647
Station XXIX, center of Sage Plateau	107	47	45	40	23	35	7,375
Station XXX, western end of Sage Plateau	107	51	30	40	28	0	7,010
Station XXXI, highest point Junction Plateau	107	32	52	40	22	5	7,637
Station XXII, northern rim Junction Plateau	107	41	25	40	20	50	7,462
Station XXXIII, southwest of Yampa and Williams Fork Junction	107	40	0	40	25	40	7,358
Station XXXIV, southeast of Waddel and Williams Fork Junction	107	34	15	40	30	40	7,840
Station XXXV, near pass over ridge between Yampa and Williams' Fork	107	28	15	40	25	0	8,000

* Longitude and latitude are omitted only in such cases where reference is made to a large area. Their locations will be found, however, by consulting the accompanying map.

Approximate geographical positions and elevations, &c.—Continued.

Names of located points.	Longitude.			Latitude.			Elevation in feet.
PASSES AND DIVIDES.							
Pass over ridge from Yampa River to Williams Fork	107	27	45	40	25	30	7, 800
Yellow Jacket Pass	107	44	0	40	9	0	7, 493
Pass between Citadel Plateau and Danforth Hills	108	6	7	40	18	0	7, 800
Pass at head of Vale Disappointment	108	33	0	40	21	0	7, 550
Divide near Pass Butte	107	40	0	40	14	0	7, 000
PARKS, BASINS, RIVER JUNCTIONS, AND CROSSINGS.							
Crossing of government road on Yampa River	107	26	0	40	30	0	6, 310
Crossing of government road on Williams Fork	107	30	0	40	21	25	6, 600
White River Ute agency	107	48	30	40	14	7	6, 491
West-Axial Basin		(*)			(*)		6, 000
Junction of Waddel Creek and Williams Fork	107	36	30	40	22	0	6, 400
Junction of Milk Creek and Yampa River	107	44	25	40	24	0	6, 275
Junction of Snake and Yampa Rivers, Lily's Park	108	24	25	40	27	0	5, 840
West end of Lily's Park	108	29	0	40	27	15	5, 800
Junction of Green and Yampa rivers	108	58	30	40	31	30	5, 500
Junction of Unga-too-wis Wash and White river	108	0	30	40	1	0	6, 165
Junction of Deep Channel Creek and White River	108	20	0	40	10	0	5, 640
Junction of Fox Creek Wash and White river	108	28	0	40	11	15	5, 560
Junction of Weary Mule's Wash and White river	108	36	45	40	9	25	5, 450
Junction of Unga-too-roosh Wash and White river (Raven Park)	108	50	0	40	5	0	5, 370
Center of Coyote Basin	108	15	0	40	15	0	6, 200

* Longitude and latitude are omitted only in such cases where reference is made to a large area. Their locations will be found, however, by consulting the accompanying map.

PART III.

ARCHÆOLOGY AND ETHNOLOGY.

REPORT OF WILLIAM. H. HOLMES.

LETTER OF TRANSMITTAL.

WASHINGTON, *March* 1, 1878.

SIR: I submit herewith my report on the ruins of Southwestern Colorado for the years 1875 and 1876. A preliminary report on the investigations made in 1875 has already been published in the second volume of the Survey bulletins. As the edition of this publication was very limited, it has been thought best to republish that report with corrections and additions, in connection with the report for 1876.

Very respectfully, your obedient servant,

WM. H. HOLMES.

Dr. F. V. HAYDEN,
United States Geologist in charge.

REPORT ON THE ANCIENT RUINS OF SOUTHWESTERN COLORADO, EXAMINED DURING THE SUMMERS OF 1875 AND 1876.

By W. H. Holmes.

In addition to my duties as geologist to the southwest or San Juan division of the survey for 1875, I was assigned the very agreeable task of making examinations of such ancient remains as might be included in the district surveyed; also in 1876, in company with Mr. Wilson, director of the primary triangulation, I revisited the northern border of the same district and made additional observations.

Previous to 1875 much information had already been given to the public in relation to the ruins of Southwestern Colorado by Mr. Jackson, who paid them a short visit in 1874, and many similar remains had been described by early explorers in New Mexico and Arizona, but nothing like a complete survey of this particular region had been made.

The district examined by our party covers an area of nearly 6,000 square miles, chiefly in Colorado, but which includes narrow belts in the adjacent Territories of New Mexico, Utah, and Arizona. It lies wholly on the Pacific slope, and belongs almost entirely to the drainage-system of the Rio San Juan, a tributary of the Colorado of the West.

Lying along the west base of the mountains is a comparatively flat country, the eastern border of the great plateau-region that reaches westward toward the Sierras. The surface-geology is chiefly Cretaceous, and the various large streams formed on the west slope of the Rocky Mountains have cut long cañoned valleys down through the nearly horizontal beds. In the greater part of this region there is little moisture apart from these streams, and, as a consequence, vegetation is very sparse, and the general aspect of the country is that of a semi-desert. Yet there is bountiful evidence that at one time it supported a numerous population; there is scarcely a square mile in the 6,000 examined that does not furnish evidence of previous occupation by a race totally distinct from the nomadic savages who hold it now, and in many ways superior to them.

At first, it seems strange that a country so dry and apparently barren as this now is could support even a moderate population, and it is consequently argued that the climate has grown less moist since the ancient occupation. Be this as it may, I observe the fact that the great bulk of remains are on or in the immediate neighborhood of running streams, or by springs that furnish a plentiful supply of water during the greater part of the year. The ever-present pottery may in many cases have been broken and left by hunting and wandering parties, and the remnants of dwellings far out from water may have been but temporary abodes used only in the winter or during rainy seasons.

I also notice that the country is by no means an entire desert. All along the stream-courses, there are grass-covered meadows and broad belts of alluvial bottom, affording, if properly utilized, a considerable area of rich tillable land.

The ruins of this region, like most others of the extreme West and South, are the remnants in a great measure of stone structures. To what extent wood and adobe were used can hardly be determined. It is evident, however, that a great portion of the villages and dwellings of the lowlands have been of material other than stone, frequently doubtless of rubble and adobe combined.

As to situation, they may be classed very properly under three heads: (1) lowland or agricultural settlements; (2) cave dwellings; and (3) cliff-houses or fortresses.

Those of the first class are chiefly on the river-bottoms, in close proximity to water, in the very midst of the most fertile lands, and located without reference to security or means of defence.

Those of the second are in the vicinity of agricultural lands, but built in excavations in low-bluff faces of the Middle Cretaceous shales. The sites are chosen also, I imagine, with reference to security; while the situation of the cliff-houses is chosen with reference to security only. They are built high up in the steep and inaccessible cliffs, and have the least possible degree of convenience to field or water.

As to use, the position for the most part determines that. The lowland ruins are the remains of agricultural settlements, built and occupied much as similar villages and dwellings are occupied by peaceable and unmolested peoples of to-day. The cave-dwellers, although they may have been of the same tribe and contemporaneous, probably built with reference to their peaceable occupations as well as to defense, but it is impossible to say whether or not they made these houses their constant dwelling-places. The cliff-houses could only have been used as places of refuge and defense. During seasons of invasion and war, families were probably sent to them for security, while the warriors defended their property or went forth to battle; and one can readily imagine that when the hour of total defeat came, they served as a last resort for a disheartened and desperate people.

In form, the parallelogram and circle predominate, and a considerable degree of architectural skill is displayed. Where the conformation of the ground permits, the squares are *perfect* squares and the circles *perfect* circles. The greater part of the ordinary structures are square or rectangular; while attached to each group, and sometimes without indications of contiguous buildings, are circular ruins frequently resembling towers. These are the most pretentious structures, being often as much as forty feet in diameter, and in many cases having double or triple walls. They are solidly built of hewn stone, dressed on the outside to the curve, neatly jointed, and laid in mortar.

In the larger towers the space between the outer walls is invariably divided by heavy partition-walls into a number of apartments, while a circular depression, or *estufa*,* occupies the centre of the enclosure.

It seems evident, from the extraordinary form of these structures and the unusual care shown in their construction, that they were not designed for the ordinary uses of dwelling or defence. It has been observed that, among nearly all the ancient tribes of North America, the grandest and most elaborate works of art were the offspring of their superstitions, and it does not seem at all improbable that these great towers had a religious origin.

In the inhabited pueblos of to-day there are underground rooms, frequently circular, used as council-chambers as well as for the performance of the mysterious rites of their religion. Similar chambers occur,

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* A Spanish word signifying "sweat-house" or council-house.

according to Lieutenant Simpson,* in all the ruined cities of New Mexico, but having single walls of no great height or thickness. It is stated by Squier and Davis† that in Mexico the sacred enclosures were also used for defensive purposes, and it certainly seems probable that these curious structures served both as temples and fortifications, and that the apartments between the walls were the receptacles of sacred or valuable property.

The smaller single-walled towers, which are scattered at intervals along the river-courses and cañons, frequently in commanding situations, were probably watch or signal towers.

The cave-dwellings are made by digging irregular cavities in the faces of bluffs and cliffs formed of friable rock, and then walling up the fronts, leaving only small doorways, and an occasional small window at the side or top.

The cliff-houses conform in shape to the floor of the niche or shelf on which they are built. They are of firm, neat masonry, and the manner in which they are attached or cemented to the cliffs is simply marvelous. Their construction has cost a great deal of labor, the rock and mortar of which they are built having been brought for hundreds of feet up the most precipitous places. They have a much more modern look than the valley and cave remains, and are probably in general more recent, belonging rather to the close than to the earlier parts of a long period of occupation. Their position, however, has secured them in a great measure from the hand of the invader as well as from the ordinary effects of age.

Of works of art other than architectural that might assist in throwing light upon the grade of civilization reached by these people, but meagre discoveries were made; although I imagine that careful search and well-conducted exhumation might develop many things of great interest. A considerable number of arrow-heads, stone implements, ornaments, and articles of fictile manufacture, that may fairly be attributed to the age of the cliff-builders, were collected. The greater part of these are figured in plates XLIV, XLV, and XLVI.

There are no evidences whatever that metals were used.

Numerous rock-inscriptions were observed, both engraved and painted upon the cliffs. Drawings of a large number were made, and some of the more notable examples are given in plates XLII and XLIII. A large number of burial places, or what we are led to believe are such, were visited. The only localities which have yielded human remains are in the valleys and in the vicinity of ancient ruins. Three entire skeletons were obtained; one from the banks of Hovenweep Creek, near the ruin known as Hovenweep Castle;‡ the others from a freshly excavated arroyo in an ancient village near Abiquiu, New Mexico.§ A skull was obtained by Captain Moss from a grave on the Rio San Juan near the mouth of the Mancos, but no particulars of the position of the skeleton or manner of burial were obtained. Two entire specimens of earthen vessels‖ were found with the skeleton.

The greater portion of what are supposed to be burial places occur on the summits of hills or on high, barren promontories that overlook the valleys and cañons. In these places considerable areas, amounting in some cases to half an acre or more, are thickly set with rows of stone

* Expedition to the Navajo Country, p. 78, &c. See also, Mr. Jackson's report.
† Ancient monuments of the Mississippi Valley, p. 102.
‡ Described by Mr. Jackson, Report U. S. Geol. Surv., 1874, 1876, p. 381.
§ The crania obtained are described by Dr. Bessells in Bulletin U. S. Geol. Survey, Vol. ii, No. 1, pp. 47–63.
‖ Mr. Jackson's report.

slabs, which are set in the ground and arranged in circles or parallelograms of greatly varying dimensions. At first sight the idea of a cemetery is suggested, although on examination it is found that the soil upon the solid rock surfaces is but a few inches deep, or if deeper, so compact that with the best implements it is very difficult to penetrate it.

On the west bank of the Dolores, near the second bend, I came upon a cluster of these standing stones on the summit of a low, rounded hill, and in the midst of a dense growth of full-grown piñon pines. Scattered over the ground were many fragments of the ordinary varieties of pottery, together with arrow-points and chips of obsidian, agate, and quartz.

The rows of stones were arranged to inclose a number of parallelograms that would probably average 3 feet by 8 in dimensions. The stones were generally quite flat, and never more than 2 feet in length or width. They were not perceptibly cut or dressed. Many of them had fallen over and lay strewn irregularly about, while few of them were buried deeper than a few inches. The soil, however, was unusually firm, and it was with the greatest difficulty that we succeeded in penetrating to the depth of 2 feet. Near the surface were a few thin layers of bits of pottery and charcoal, but at 6 inches in depth the soil had apparently never been disturbed.

That the placing of these stones occurred at a very early date is attested by the growth of forest, which is at least three or four hundred years old. In a number of cases the stones are deeply embedded in the sides and roots of the trees.

At two other localities near the south bend of the Rio Dolores I observed similar groups of standing stones, about which was the usual accompaniment of pottery and flint chips.

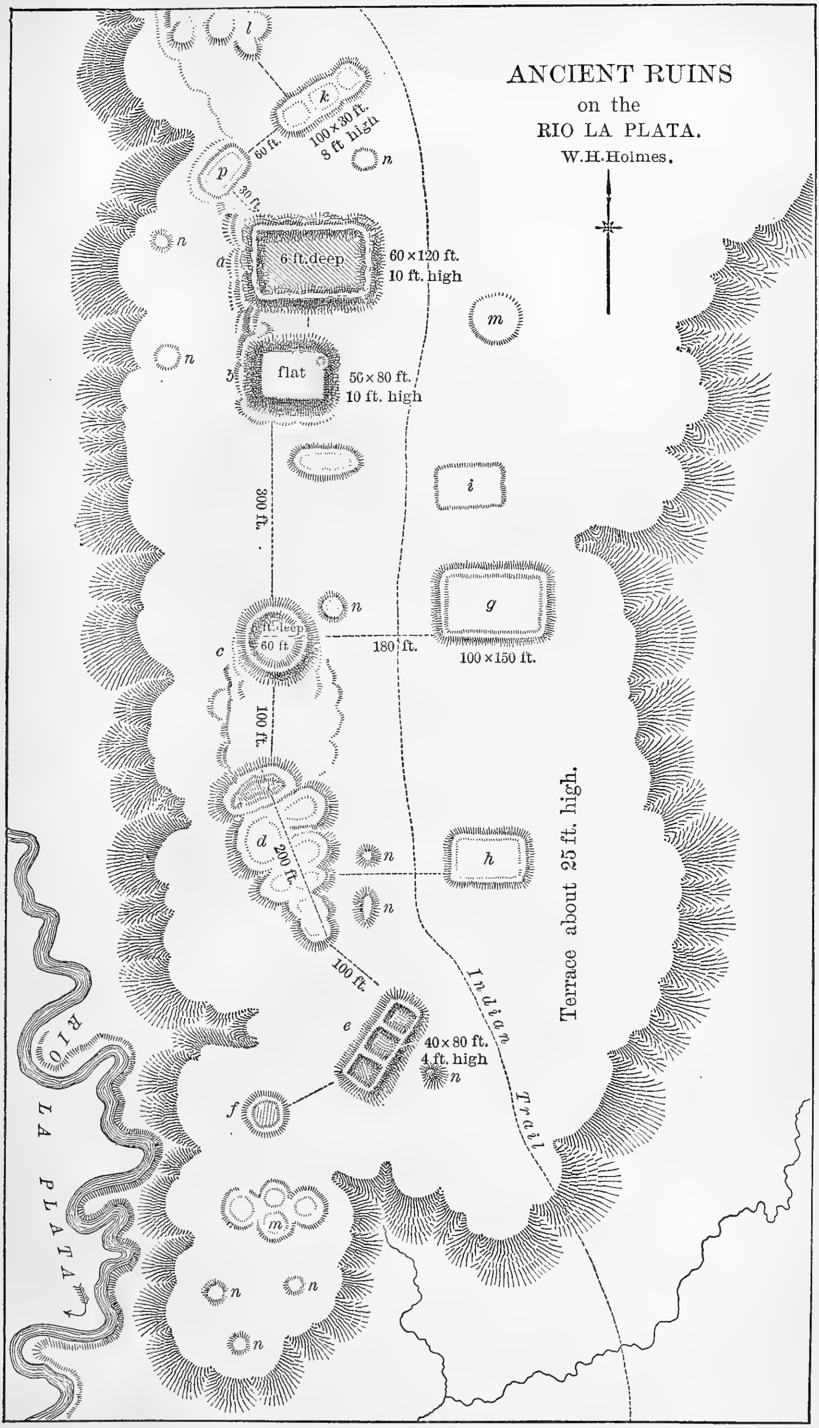
On a high promontory between the McElmo and Hovenweep cañons, at their junction, I discovered a fine group of similar remains. Here a number of the enclosures were circular, and in a few cases were as much as 20 feet in diameter. A full description of this locality will be found in Mr. Jackson's report.

The impression that these places, if not actually burying-grounds, were at least places used for the performance of funeral rites is confirmed by the well-known fact that many of the American tribes perform these rites in similar situations, the remains of the dead being burned or left to decay in the open air.

The occurrence of such quantities of pottery and arrow-points suggests the idea that these, and perhaps other more destructible articles, may have been left with the dead to be used by the departed spirit on its way to the "happy hunting grounds."

The accompanying plates are, with a few exceptions, reproductions of pen-drawings. The plans are not drawn to a uniform scale, because of the inconvenience of such an arrangement; but measurements are so frequently given on the plates themselves that no confusion need occur. Measurements were taken by tape-line in all the more important structures; but in many of the ordinary ruins, where exact dimensions were not considered essential, the distances were estimated. It is to be greatly regretted that extreme haste frequently prevented close and accurate work.

The map which follows this report will give the location of all the more important groups of ruins.


ANCIENT RUINS
on the
RIO LA PLATA.
W.H.Holmes.
100 x 30 ft.
8 ft high
60 ft.
30 ft.
6 ft. deep
60 x 120 ft.
10 ft. high
flat
50 x 80 ft.
10 ft. high
300 ft.
6 ft. deep
60 ft.
180 ft.
100 x 150 ft.
100 ft.
200 ft.
100 ft.
40 x 80 ft.
4 ft. high
Terrace about 25 ft. high.
Indian Trail
RIO LA PLATA

RUINED VILLAGE ON THE RIO LA PLATA.

Plate XXX.

The first group of ruins observed is situated on the Rio La Plata, about twenty-five miles above its junction with the San Juan, and five miles south of the New Mexican line. It is doubtless the remains of a large irregular village, and stands on a low terrace, some 20 feet above the river-bed, and near the centre of a large, fertile valley.

It will be seen, by reference to the plate, which includes only the more important part of the town, that the buildings have been isolated, and, in a measure, independent of each other, differing in this respect from most of the groups of ruins farther south and west.

The forms are chiefly rectangles and circles; one or two seem to have been elliptical, while a number have consisted of irregular groups or clusters of apartments. All that now remains to mark the site of these ancient structures are the low, rounded heaps and lines of *débris*, composed of earth, water-worn pebbles, and small fragments of sandstone. The walls of four of the main structures are quite distinctly marked. That of the circle *c* is still 4 feet high on the outside, and incloses a depression, probably an *estufa*, which, in the center, is 2 or 3 feet below the terrace-level.

North of this, about 300 feet, is a truncated rectangular mound, 9 or 10 feet in height and 50 feet in width by 80 in length. On the east end, near one of the angles, is a low, projecting pile of *débris* that may have been a tower. There is nothing whatever to indicate the use of this structure. Its flat top and height give it more the appearance of one of the sacrificial mounds of the Ohio Valley than any other observed in this part of the West. It may have been, however, only a raised foundation, designed to support a superstructure of wood or adobe.

North of this, again, and 100 feet distant, is a rectangular inclosure about 60 by 100 feet. It is slightly excavated in the centre, and the rounded and irregular wall is from 4 to 6 feet in height. The space between this and the last-mentioned structure is filled in to the depth of 2 or 3 feet, and the amount of *débris* about their bases indicates original walls of considerable height. North of this are scattered a number of inferior ruins, the walls of which are not always distinctly marked. These extend back toward a row of low hills, the remnants of a superior terrace, on the summits of which a number of artificial depressions were found. Such "dug holes" are generally quite numerous in the vicinity of these ruins, and have doubtless in many cases been made by throwing up earthworks for defensive purposes. South of the large circle is a mass of ruins covering some 15,000 square feet, but so much reduced that nothing further could be determined than the fact that it had contained a large number of irregular apartments. Next to this is a rectangular ruin, containing three well-marked apartments. Its walls are 6 or 7 feet high, and, unlike those of the preceding examples, do not coincide with the cardinal points. South of this, and occupying the extreme southern end of the terrace, are a number of small circles and mounds, while an undetermined number of diminutive mounds are distributed among the other ruins.

To the east of the Indian trail, as shown in the plate, are a number of inclosures of lesser importance, which, from want of time, were not closely examined.

Nowhere about these ruins are there any considerable indications of defensive works, and the village, which is scattered over an area fully

two miles in circuit, has no natural defensive advantages whatever. Neither are there traces of ditches, nor of anything that might throw important light upon the habits or occupations of the people. A few arrow-heads and minute cutting-implements were picked up. Countless chips of jasper, obsidian, and flint were scattered around, and the soil was literally full of fragments of painted and indented pottery.

On the opposite side of the river, and at intervals above and below, are isolated groups of ruins and heaps of *débris*—certainly the remains of dwellings. These seem to be distributed very much as dwelling-houses are in the rural districts of civilized and peaceable communities.

It is possible that there are undiscovered ruins on this stream equally important with those described; for, in pursuing my geologic investigations, I was compelled to take a long detour to the westward from this point, returning to the La Plata again a few miles above its junction with the San Juan. On this occasion, while riding through a desert-like locality, quite naked and barren, much resembling the well-known *Mauvaises terres*, I was surprised to observe fragments of pottery strewn around, and presently a number of ruins, in a very reduced state and almost covered by the drifting sand, and this six or eight miles from water. On the high, dry table-lands, on all sides, fragments of pottery were picked up. What could have induced people to build and dwell in such a locality it is useless to surmise.

GROUP OF CAVE-DWELLINGS AND TOWERS ON THE RIO SAN JUAN.

Plate XXXI.

On the San Juan River, about thirty-five miles below the mouth of the La Plata and ten miles above the Mancos, occurs the group of ruins figured in Plate II.

The river is bordered here by low lines of bluffs formed from the more compact portions of the Middle Cretaceous shales. At this particular place, the vertical-bluff face is from 35 to 40 feet in height.

I observed, in approaching from above, that a ruined tower stood near the brink of the cliff, at a point where it curves outward toward the river, and in studying it with my glass detected a number of cave-like openings in the cliff-face about half-way up. On examination, I found them to have been shaped by the hand of man, but so weathered out and changed by the slow process of atmospheric erosion that the evidences of art were almost obliterated.

The openings are arched irregularly above, and generally quite shallow, being governed very much in contour and depth by the quality of the rock. The work of excavation has not been an extremely great one, even with the imperfect implements that must have been used, as the shale is for the most part soft and friable.

A hard stratum served as a floor, and projecting in many places made a narrow platform by which the inhabitants were enabled to pass along from one house to another.

Small fragments of mortar still adhered to the firmer parts of the walls, from which it is inferred that they were at one time plastered. It is also extremely probable that they were walled up in front and furnished with doors and windows, yet no fragment of wall has been preserved. Indeed, so great has been the erosion that many of the caves have been almost obliterated, and are now not deep enough to give shelter to a bird or bat.

This circumstance should be considered in reference to its bearing

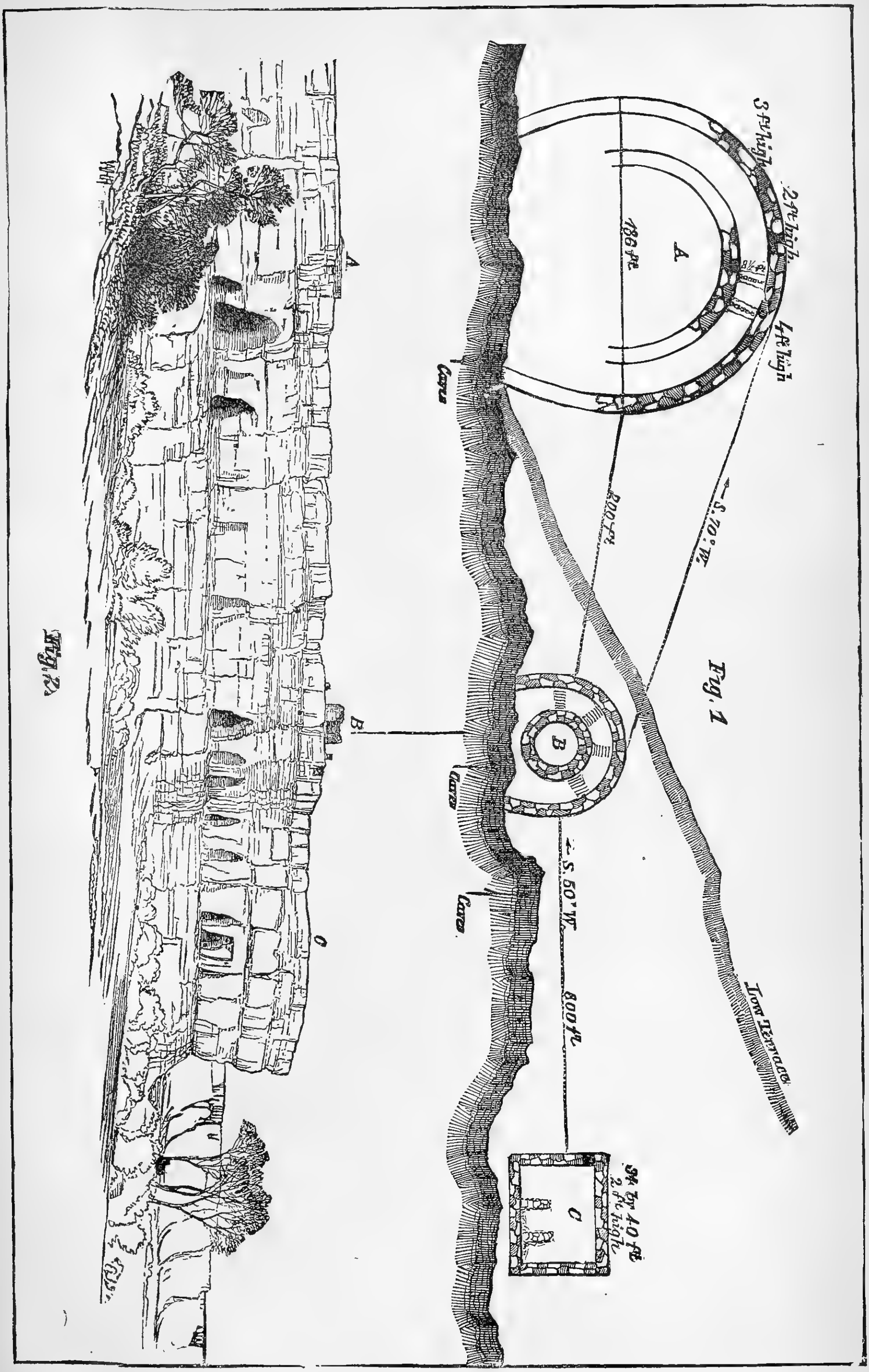


Fig. 1
Fig. 2
A
186 ft
3 ft high
2½ ft high
4 ft high
800 ft
S. 70° W.
B
Cave
Cave
Cave
S. 50° W.
800 ft
Low Terrace
C
34 by 40 ft
2 ft high

upon the question of antiquity. If we suppose the recess to be destroyed is six feet deep, the entire cliff must recede that number of feet in order to accomplish it. If the rock were all of the friable quality of the middle part, this would indeed be the matter of a very few decades; but it should be remembered that the upper third of the cliff-face is composed of beds of comparatively hard rocks, sandstones, and indurated shales. It should also be noted still further that at the base of the cliff there is an almost total absence of *débris*, or fallen rock, or even of an ordinary talus of earth, so that the period that has elapsed since these houses were deserted must equal the time taken to undermine and break down the six feet of solid rock, plus the time required to reduce this mass of rock to dust; considering also that the erosive agents are here unusually weak, the resulting period would certainly not be inconsiderable.

Figure 2 gives a fair representation of the present appearance of these dwellings, while their relations to the group of ruins above will be understood by reference to Figure 1. These ruins are three in number—one rectangular and two circular. The rectangular one, as indicated in the plan C, is placed on the edge of the mesa, over the more northern group of cave-dwellings; it is not of great importance, being only 34 by 40 feet, and scarcely 2 feet high; the walls are 1½ feet thick, and built of stone.

The small tower B is situated on the brink of the cliff, directly above one of the principal groups of cave-houses. It is neatly built of stone, which, although not hewn, is so carefully chosen and adjusted to the curve that the wall is quite regular. That the stone was procured from the neighboring cliffs is indicated by the presence of great numbers of characteristic fossils. The wall is 18 inches thick and from 2 to 6 feet in height.

Long lines of *débris*, radiating from all sides, indicate that it has been much higher, and has but recently fallen. This tower is enclosed by a wall, also circular in form, but open toward the cliff, as seen in the drawing; the ends projecting forward and irregular and broken as if portions had fallen. Its construction is like that of the inner wall, but the height is not more than 3 feet at any point. The diameter of the inner circle is 12 feet, that of the outer 22 feet; the distance, therefore, between the walls is a little less than 4 feet. In this space there are indications of partition-walls that have originally divided it into a number of apartments.

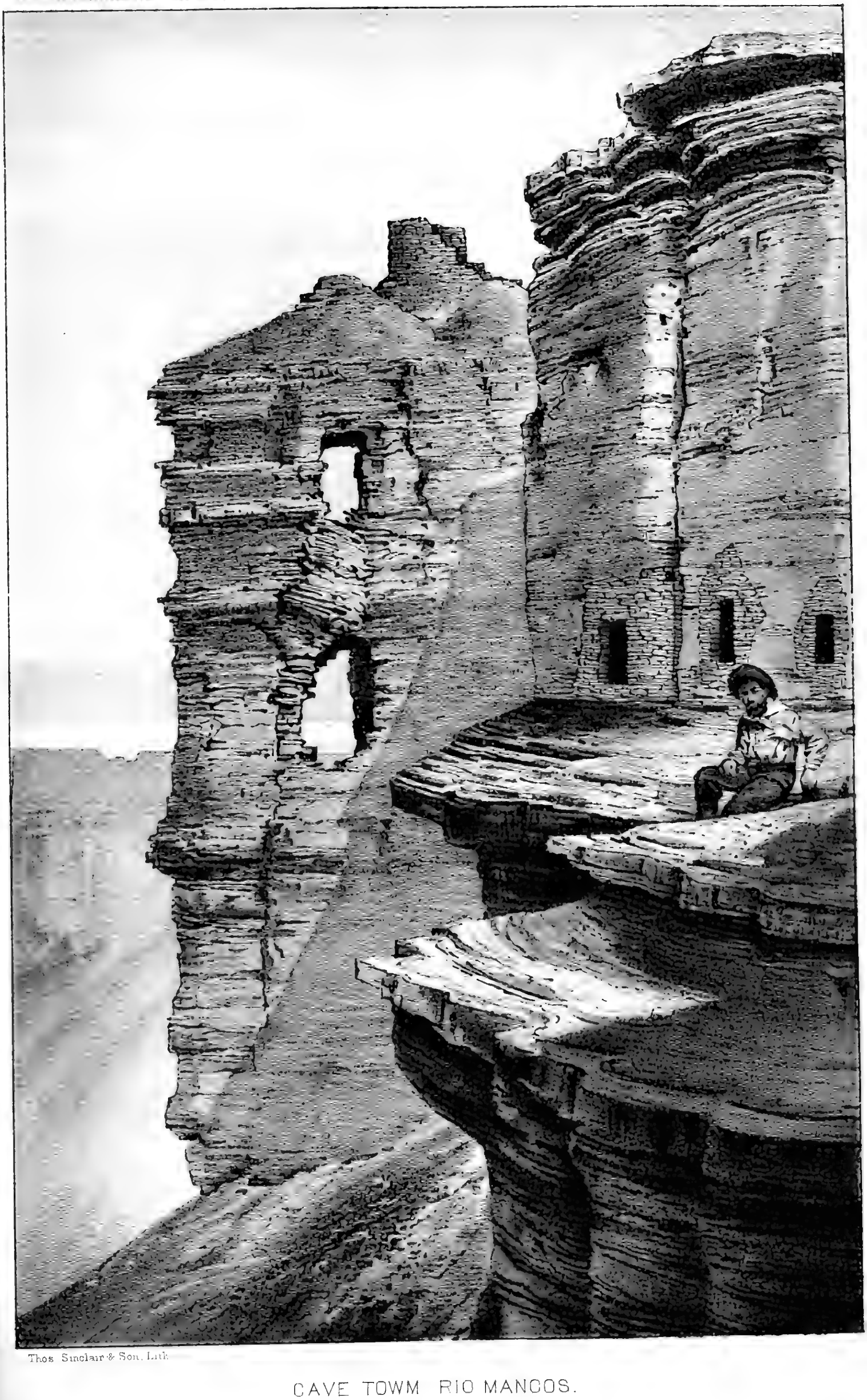
About one hundred and fifty yards to the southwest of this ruin are the remains of another similar structure. It has been, however, on a much grander scale. The walls are 26 inches thick, and indicate a diameter in the outer wall of about 140 feet. They are not above 4 feet high at any point, and in the parts toward the cliff can only be traced by a low ridge of earth. The remaining fragments of wall are at the remoter parts of the circles, and are in every respect like the walls already described. The inner wall, which can be traced but a short distance, is 8½ feet from the outer, and has been connected by partition-walls, as in the other case.

The first impression given by this curious enclosure is that it was designed for a "corral", and used for the protection of herds of domestic animals; but since these people are not known to have possessed domestic animals, and when we further consider that enclosures of pickets would have served this purpose as well as such a massive and extraordinary structure, we can hardly avoid assigning it to some other use, which use, doubtless similar to that of the smaller tower, is very naturally suggested by its location and construction.

That they both belonged to the community of cave-dwellers, and served as their fortresses, council-chambers, and places of worship, would seem to be natural and reasonable inferences. Being on the border of a low mesa country that rises towards the north, the strong outside walls were doubtless found necessary to prevent incursions from that direction, while the little community by means of ladders would be free to pass from dwelling to temple and fortress without danger of molestation.

The original height of these structures must necessarily be a matter of conjecture, and it is true that although there is every evidence of age, both in the cave-dwellings and in the walled enclosures above, the lack of great quantities of crumbling walls and *débris*, and the general bareness of the ruins, give rise to the notion that they were but meagre affairs. If we conclude, however, that the outer walls were constructed for defence, and their thickness and form favor such a hypothesis, their height would probably have been as great as fifteen or twenty feet, while the inner walls, being equally heavy and well built, would be sufficiently high to accommodate two or three stories.

The manner of walling up the fronts of the cave dwellings, as here given, was observed frequently on the Rio Mancos, where, in corresponding cliffs of shaly sandstones, there are many well-preserved specimens. A large group situated on this stream, about ten miles above its mouth, was subsequently examined. The walls were in many places quite well preserved and new-looking, while all about, high and low, were others in all stages of decay. In one place in particular, a picturesque outstanding promontory has been full of dwellings, literally honey-combed by this earth-burrowing race, and as one from below views the ragged, window-pierced crags (see Plate XXXII), he is unconsciously led to wonder if they are not the ruins of some ancient castle, behind whose mouldering walls are hidden the dread secrets of a long-forgotten people; but a nearer approach quickly dispels such fancies, for the windows prove to be only the door-ways to shallow and irregular apartments, hardly sufficiently commodious for a race of pigmies. Neither the outer openings nor the apertures that communicate between the caves are large enough to allow a person of large stature to pass, and one is led to suspect that these nests were not the dwellings proper of these people, but occasional resorts for women and children, and that the somewhat extensive ruins in the valley below were their ordinary dwelling-places. On the brink of the promontory above stands the ruin of a tower, still twelve feet high, and similar in most respects to those already described. These round towers are very numerous in the valley of the Mancos. From this point alone at least three others are in view, some on the higher promontories, others quite low, within twenty or thirty feet of the river-bed. I visited and measured seven along the lower fifteen miles of the course of this stream. In dimensions they range from ten to sixteen feet in diameter and from five to fifteen feet in height, while the walls are from one to two feet in thickness. They are in nearly every case connected with other structures, mostly rectangular in form. At the mouth of the Mancos, however, a double circle occurs, the smaller one having been the tower proper. It is fifteen feet in diameter, and from eight to ten in height. The larger circular wall is forty feet in diameter and from two to four feet high, and is built tangent to the smaller. This ruin is at the point where the Mancos reaches the alluvial bottom bordering the Rio San Juan, and about one mile above its junction with that river. On the opposite or south side of the river are traces of somewhat extensive ruins, but so indistinct that the character of the original structures cannot be made out, and indeed no single mile of the lower fifty of the Mancos is without such remains.



Thos. Sinclair & Son, Lith.

CAVE TOWM RIO MANCOS.

Fig 1.

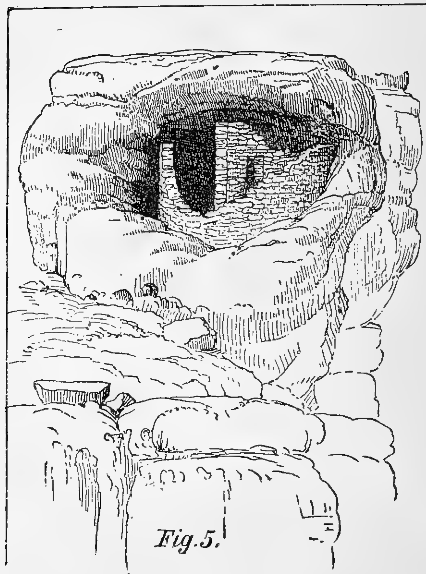


Fig. 5.

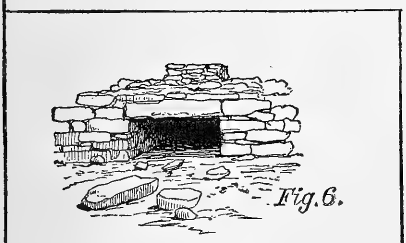


Fig. 6.

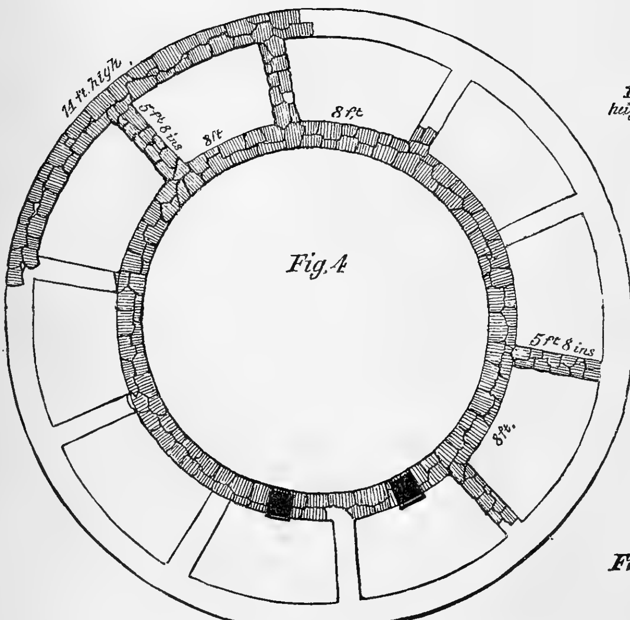


Fig. 4.

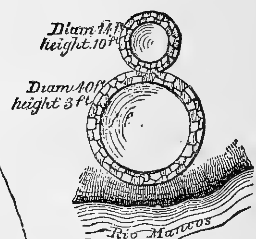


Fig. 2.

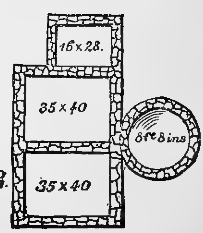


Fig. 3.

CAÑON OF THE RIO MANCOS.

Fifteen miles from its junction with the San Juan, this stream emerges from the southwest border of the Mesa Verde, through which it has cut its way, producing a most remarkable cañon. This cañon has already been once or twice described; but, in order to make my subsequent descriptions better understood, I shall give here an outline. The Mesa Verde is a somewhat irregular table-land, comprising an area of about seven hundred square miles, and is formed of a great series of nearly horizontal sedimentary rocks, of which the surrounding country has been denuded. This series of strata consists, in the upper part, of massive sandstones; in the middle part, of alternating sandstones and shales; and in the lower one thousand feet, chiefly of shales and clay. These softer beds are, when once exposed to the erosive agents, carried away with great rapidity, and, as a consequence, the firmer rocks above are undermined and break down in vertical cliffs, and, where soft and hard beds alternate, a series of steps, with intervening slopes, is formed. It will readily be seen that a cañon thus formed would consist in general of a narrow, irregular river-bottom, long steep slopes of *débris* rising like the arms of a letter V from this, then a succession of steeps and slopes, culminating above in a series of lofty, embattled cliffs. The cañon is nearly thirty miles in length, and ranges from one to two thousand feet in depth. It seems to have been a favorite resort of the cliff-building people, and traces of their industry may be found everywhere, along the bottoms, in the cliffs, and on the high, dry table-lands above.

The six following plates will be taken up in the delineation of the more interesting portions of these remains.

PLATES XXXIII AND XXXIV.

Figure 1, Plate XXXIII, illustrates the method of walling up the cave-fronts as described on a preceding page. This sketch was made at the last-mentioned locality on the Rio Mancos. The group occurred in the cliff about thirty feet from the base. The three door-ways opened into as many small apartments, and these were connected with each other by very small passage-ways. The farther door could not be reached from the outside, as the platform of rock had broken away. See foreground in Plate XXXII.

Figure 2 gives a plan of the double tower near the mouth of the Mancos; it has already been described.

The ruin, of which a plan is given in Figure 3, occurs on the left bank of the Mancos about eight miles above the foot of the cañon. It is one of the best preserved specimens of the ruined towers, and seems to have been built with much skill. (See Plate XXXIV.) It is 9 feet in diameter on the inside and about 16 feet high. There are three rectangular apartments attached, the walls of which are almost levelled with the ground. In the side of the tower facing the river is a window, about 8 feet from the ground and 2 feet high by $1\frac{1}{2}$ wide. I had been previously led to the conclusion that these towers were in all cases built without windows or openings of any kind within reach of the ground from without, and it is not improbable that this opening did not communicate with the outside, but served as a door-way between the tower and one of the adjoining apartments. The advantage of such an arrangement in a defensive work, such as we may suppose this to have been, is clearly apparent, and evinces not a little intelligence and forethought on the part of the builders. Being built in connection with dwellings and places

of resort, they could, in case of alarm, be reached with ease from within, but be altogether secure from without.

Figure 4. The large circular ruin, of which a ground-plan is given in this plate, was also visited by Mr. Jackson, photographs were made, and a brief description given; but I deem it best to give a more detailed description, the result of such observations and measurements as could be made in a period of time entirely too short for a work of such importance.

This ruin is situated on a narrow strip of alluvial bottom about midway in the cañon of the Mancos. On first approaching it, one does not observe that it differs greatly from the ordinary fragmentary structures below, as it is much decayed and almost hidden by artemisia and vines. Closer inspection, however, develops the greater part of the outline, and I imagine that a little excavation would bring all the foundations to light. The inner wall can be traced throughout the entire circle, and is in places 6 or 8 feet high. A portion of the outer wall, at the point farthest from the river, is still 12 feet in height and in a fair state of preservation. The space between the walls has been divided into cells, as in the two examples given in Plate XXXI. Four of the cross-walls are still a number of feet high, while others can be traced by lines of *débris*. The diameter of the outer wall is 43 feet; that of the inner, 25 feet. They are faced up with larger stones than usual (the heaviest of which, however, could be lifted with ease by a single workman), and have been filled in with rubble, adobe, and wood. The outside courses have been dressed to the curve, and the implements used, judging from the appearance of the picked surfaces, have been of stone. The main walls are 21 inches in thickness, while the partition-walls are somewhat lighter, and seem to have been but slightly built into the circular walls.

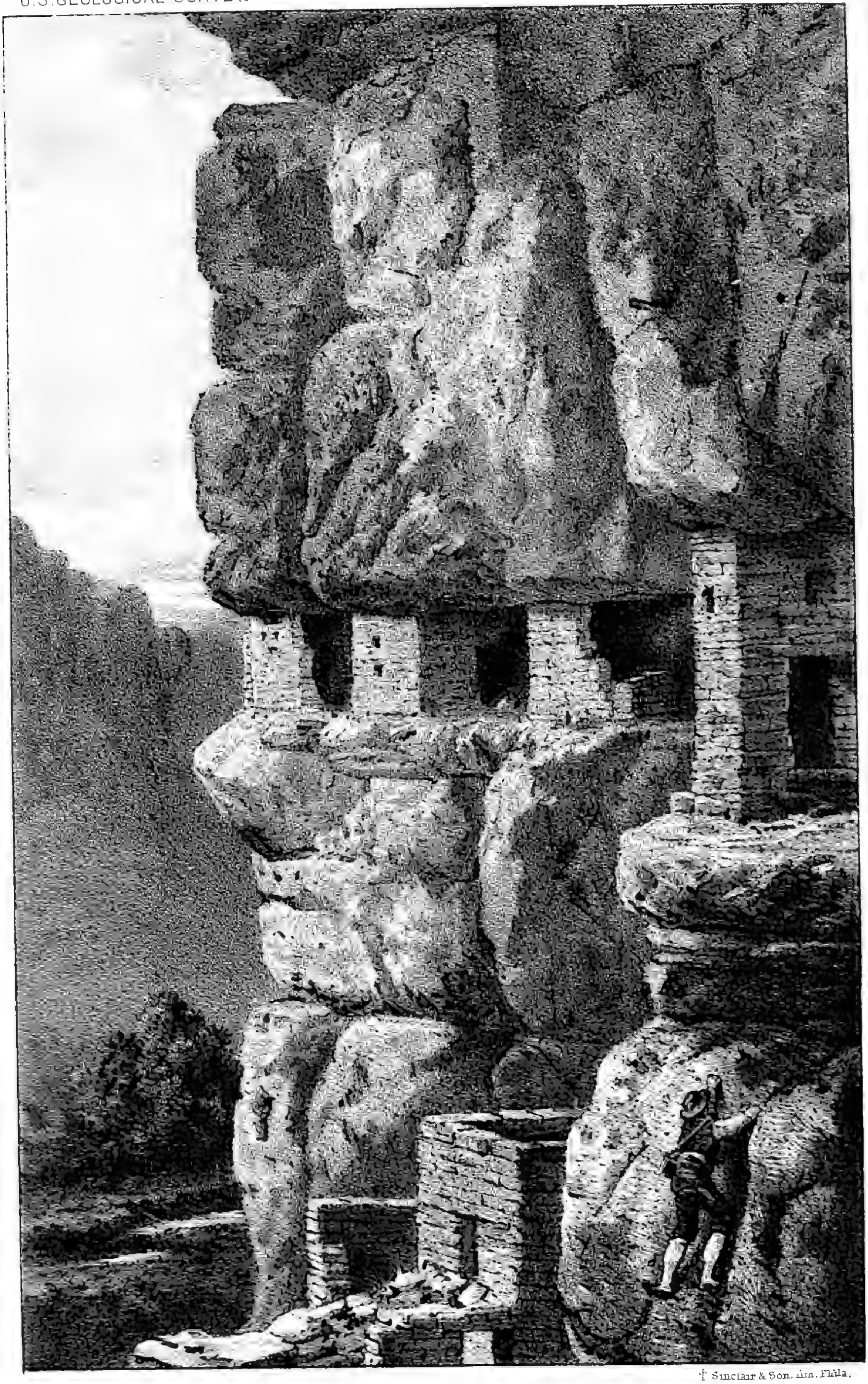
In order to determine the probable number of these cells, I measured the two having complete walls, and found the inner side of each to be 8 feet. As these were both on one side of the circle, I had but to measure the remaining space to complete the semicircle, and on so doing found that there was just room for three additional cells and the necessary partition-walls; two of these were still traceable. To complete the circle, therefore, ten apartments would be necessary. Being desirous of confirming this conclusion, I took the diameter of the inner circle, as given in my notes, and, by adding twice the thickness of the wall, obtained a circumference of 89½ feet; just sufficient space to accommodate ten apartments, with an equal number of partition-walls a fraction less than 12 inches in thickness.

By adding to the diameter of the inner circle the total thickness of the walls, plus twice the distance between them, I obtained a diameter of 43 feet for the outer circle. The circuit of the structure is, therefore, 135 feet. Although these figures are greater than those previously given (estimated), I am confident that they cannot vary greatly from the truth.

There were no indications of windows or doors in the fragment of outer wall, but two nearly rectangular openings in the inner wall seem to have served as door-ways between the central enclosure and the cells. We may suppose that each cell had similar means of communication with the interior. The one door-way that remains entire is 6 feet from the ground, and measures 2 feet in width by 3 in height. The stone-work of the facing is very neat and exact, and the lintel is of a single slab of sandstone. It may be fairly presumed that the outer wall had no door-ways or windows within reach of the ground, and that entrance was obtained, by means of ladders, through high windows or by way of

Thos. Sinclair & Son, Lith.

HIGH TOWER RIO MANCOS.



† Sinclair & Son. lith. Phila.

CLIFF HOUSES, RIO MANCOS.

the roof. The central enclosure has doubtless served as an *estufa*, and there are still evidences of a considerable depression.

That this ruin is quite ancient is attested by the advanced stage of decay, and that it has been of considerable height may be inferred from the large quantities of *débris*. A similar and somewhat more perfect example of double-walled tower is illustrated in Plate XXXIX.

There seem to have been no buildings of importance in connection with this ruin, but many in the vicinity. On the point of a low rocky promontory that extends down from the mesa on the west to within a few yards of the circular ruin are some masses of decaying wall, and a large circular depression, not differing in appearance from the usual *estufa*.

It is probable that there are other remains higher up on the rocky slope; indeed, others could be seen from the trail, but I found no time to visit them.

A few hundred yards below the great tower, and very near the trail, a smaller tower occurs, having other ruins connected with it, and in a weather-worn cavity in a massive crag near by is the cosy little dwelling shown in Figure 5.

The rude little fire-place illustrated in Figure 6 was observed by Mr. Brandegee in connection with a cliff-house on the opposite side of the cañon, a little farther up. It is remarkable as being the only example discovered by our party. There seem to be no traces whatever of fire-places, ovens, furnaces, or chimneys in or about any of the ruins described, which is rather remarkable, since fires must have been used in baking pottery and for domestic purposes, and we cannot suppose that a people so well advanced in architectural skill were unable to build fire-places and furnaces.

PLATE XXXV.—CLIFF-HOUSES OF THE MANCOS.

This plate illustrates one of the more interesting groups of cliff-houses, or fortresses of the Rio Mancos. It occurs about ten miles from the foot of the cañon in a subordinate cliff on the west side. This low cliff is of massive sandstone, and is washed by the river, the trail being crowded back against the steep wall. At the height of about 40 feet above the river, a bed of shale occurs in the sandstone, which, being easily disintegrated, has been weathered out and carried away, leaving a sort of horizontal groove some 4 feet high and from 4 to 6 feet deep. In this a row of diminutive houses has been built. Three of these are almost perfect, having a fresh new look that certainly belies their age. Four others are much more decayed, and fragments of wall only cling to the cliffs. They have been made to occupy the full height and depth of the crevice, so that when one reaches it at the only accessible point, he is between two houses and must pass through these to get at the others. The door-ways are quite small and bear no evidence of the fitting or hanging of doors; and the windows, of which a number open to the front, are but a few inches square.

The walls are strongly built and are from eight to ten inches thick. The stones are small, dressed roughly on the outside, and laid in mortar.

In many places the heavier seams of mortar have been chinked with bits of pottery and small flakes of sandstone. The marks of the masons' pick are as fresh as if made within a few years, and the fine, hard mud-mortar which has been applied with the bare hands, still retains impressions of the minute markings of the cuticle of the fingers.

The house at the left hand in the drawing has two apartments, the

farthest of which has a curved wall conforming with the rounded end of the crevice floor, which, beyond this for some distance, is broken down.

Specimens of the mortar and of the dressed stone were procured from this house and brought East. Below the middle part of this line of houses, on an irregular projection, are the remains of a number of walls, in such a state of ruin, however, that the character of the original structure could not be made out. In digging among the *débris* of this ruin, I came upon a bin of charred corn, in which the forms of the ears were quite perfect. This corn seems to be of a variety similar to that cultivated by the tribes of the neighborhood at the present time.

That this corn had been placed there by the ancient occupants seems probable from the fact that it occupied a sort of basement apartment or cellar, and had been buried beneath the fallen walls of the superstructures. Embedded in this mass of charcoal, I found the very perfect specimen of stone implement figured in Plate XLVI (Figure 3). Many large fragments of the ordinary painted pottery were also picked up here. A certain new look about portions of this group leads one to suspect that it cannot boast of great antiquity; but it is very difficult to calculate the effects of age upon walls so perfectly protected and in such a climate.

PLATE XXXVI.

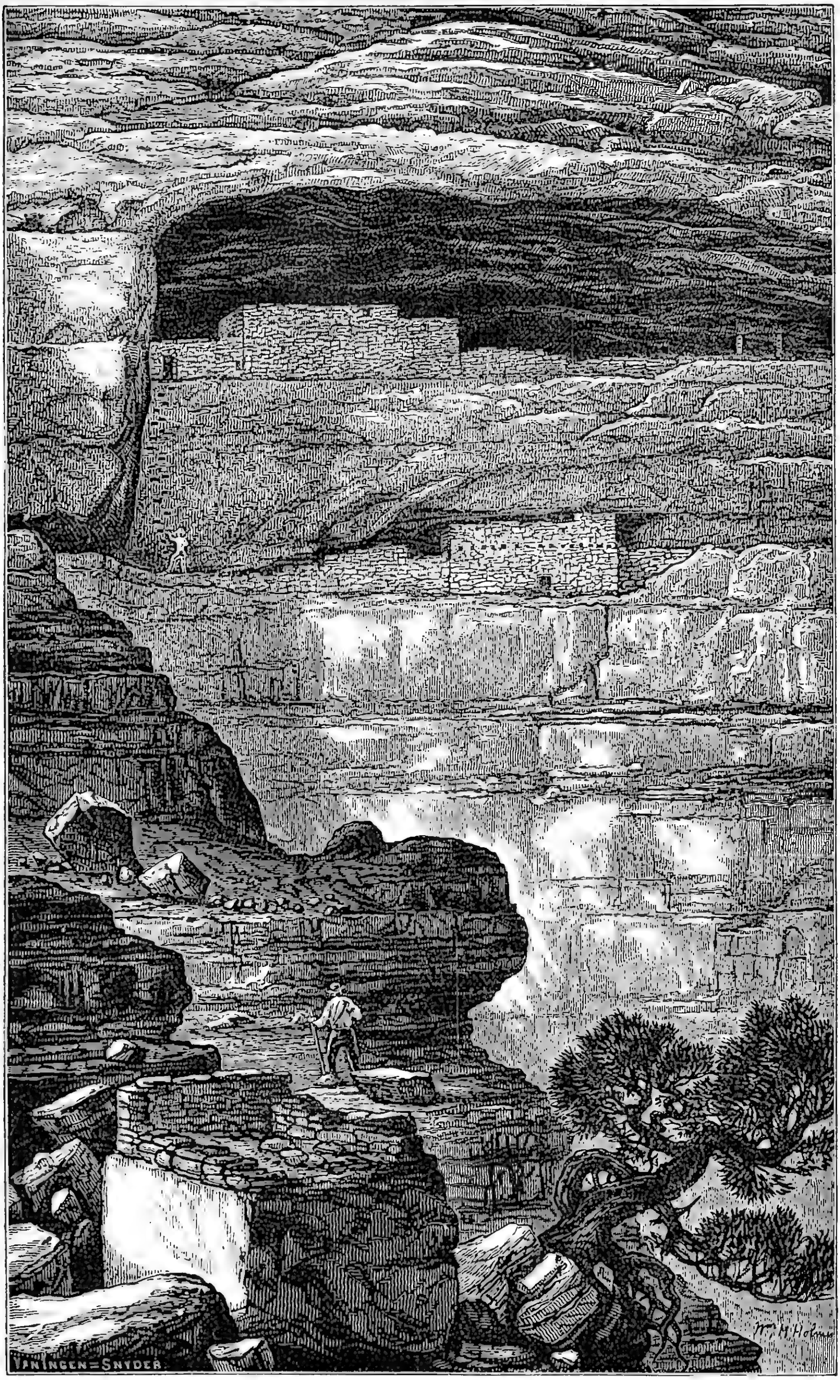
The group given in this plate is of a very interesting and remarkable character. It was first observed from the trail far below and fully one-fourth of a mile away. From this point, by the aid of a field-glass, the sketch given in the plate was made. So cleverly are the houses hidden away in the dark recesses, and so very like the surrounding cliffs in color, that I had almost completed the sketch of the upper house before the lower or "sixteen-windowed" one was detected. They are at least eight hundred feet above the river. The lower five hundred feet is of rough cliff-broken slope, the remainder of massive bedded sandstone full of wind-worn niches, crevices, and caves. Within one hundred feet of the cliff-top, set deep in a great niche, with arched, overhanging roof, is the upper house, its front wall built along the very brink of a sheer precipice. Thirty feet below, in a similar but less remarkable niche, is the larger house, with its long line of apertures, which I afterward found to be openings intended rather for the insertion of beams than for windows.

PLATE XXXVII.

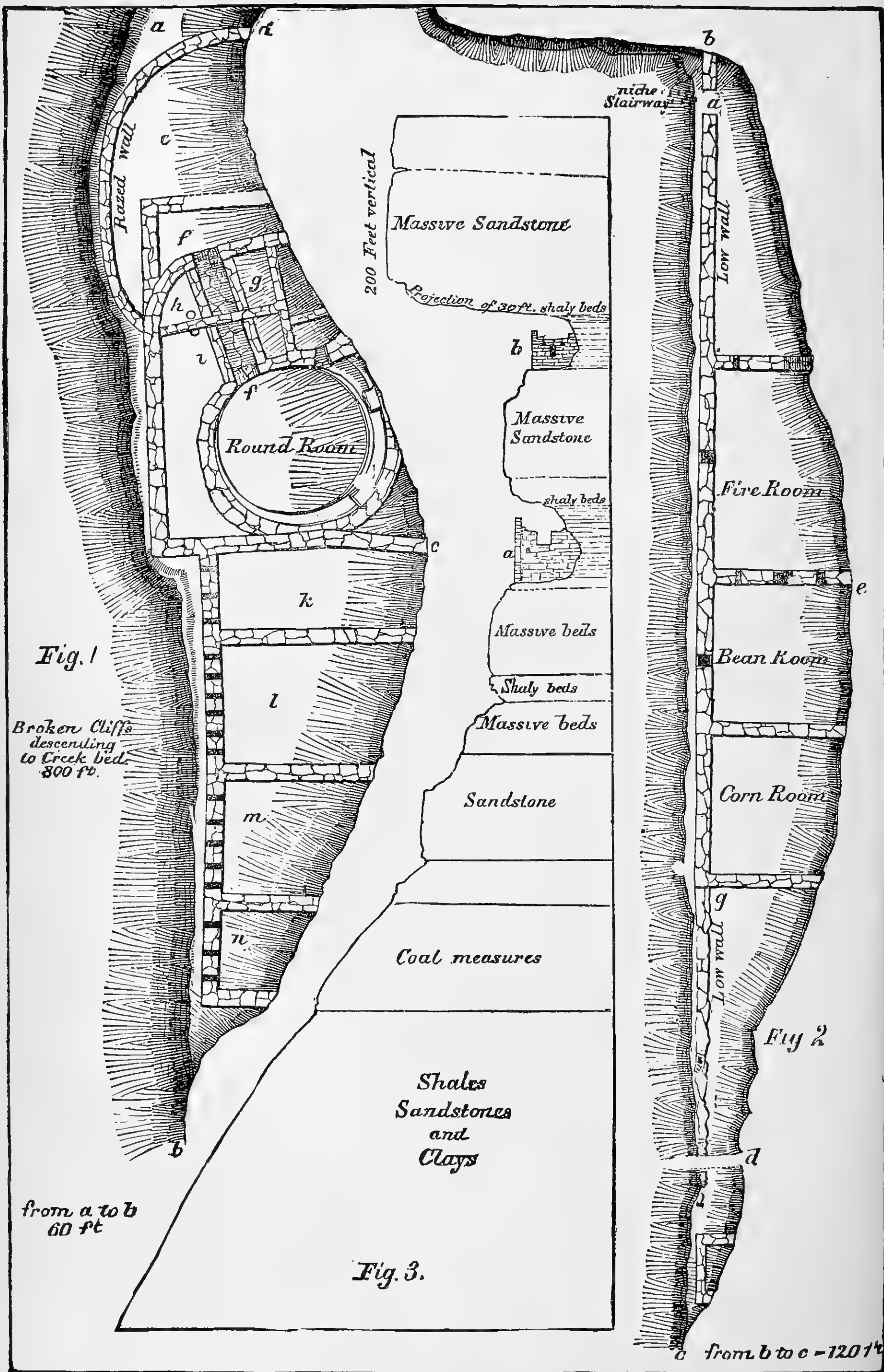
I subsequently climbed the cañon-walls to make a closer examination of these ruins, and the plans given in Plate XXXVII were obtained.

The lower house was easily accessible, and proved to be of a very interesting character. It occupies the entire floor of a niche which is about 60 feet long and 15 in depth at the deepest part. The front walls are built flush with the precipice, and the partition-walls extend back to the irregular wall of rock behind. Portions of the wall at the left, viewing the house from the front, are greatly reduced; but the main wall, that part which contains the window-like openings, is still 13 or 14 feet high.

The arrangement of the apartments is quite complicated and curious, and will be more readily understood by a reference to the ground-plan (Figure 1). The precipice-line, or front edge of the niche-floor, extends from *a* to *b*. From this the broken cliffs and slopes reach down to the



Cliff Town, Rio Mancos.


Razed wall
Round Room
Fig. 1
Broken Cliffs descending to Creek bed 800 ft.
from a to b 60 ft
200 Feet vertical
Massive Sandstone
Projection of 30 ft. shaly beds
Massive Sandstone
shaly beds
Massive beds
Shaly beds
Massive beds
Sandstone
Coal measures
Shales Sandstones and Clays
Fig. 3.
niche
Stairway
Low wall
Fire Room
Bean Room
Corn Room
Low wall
Fig 2
from b to c - 120 ft

trail and river, as shown in the accompanying profile (Figure 3). The line *b c d* represents the deepest part of the recess, against which the walls are built. To the right of *b*, the shelf ceases, and the vertical face of rock is unbroken. At the left, beyond *a*, the edge is not so abrupt, and the cliffs below are so broken that one can ascend with ease. Above, the roof comes forward and curves upward, as seen in the profile.

The most striking feature of this structure is the *round room*, which occurs about the middle of the ruin and inside of a large rectangular apartment.

The occurrence of this circular chamber in this place is highly significant, and tends greatly to confirm my previously-stated opinion that the circle had a high significance with these people. Their superstitions seem to have been so exacting in this matter that, even when driven to the extremity of building and dwelling in the midst of these desolate cliffs, an inclosure of this form could not be dispensed with; a circular *estufa* had to be constructed at whatever cost of labor and convenience.

Its walls are not high and not entirely regular, and the inside is curiously fashioned with offsets and box-like projections. It is plastered smoothly, and bears considerable evidence of having been used, although I observed no traces of fire. The entrance to this chamber is rather extraordinary, and further attests the peculiar importance attached to it by the builders, and their evident desire to secure it from all possibility of intrusion. A walled and covered passage-way, *f*, *f*, of solid masonry, 10 feet of which is still intact, leads from an outer chamber through the small intervening apartments into the circular one. It is possible that this originally extended to the outer wall, and was entered from the outside. If so, the person desiring to visit the *estufa* would have to enter an aperture about twenty-two inches high by thirty wide, and crawl, in the most abject manner possible, through a tube-like passage-way nearly twenty feet in length. My first impression was that this peculiarly-constructed door-way was a precaution against enemies, and that it was probably the only means of entrance to the interior of the house; but I am now inclined to think this hardly probable, and conclude that it was rather designed to render a sacred chamber as free as possible from profane intrusion. The apartments *l*, *k*, *m*, *n* do not require any especial description, as they are quite plain and almost empty. The partition-walls have never been built up to the ceiling of the niche, and the inmates, in passing from one apartment to another, have climbed over. The row of apertures indicated in the main front wall are about five feet from the floor, and were doubtless intended for the insertion of beams, although there is no evidence that a second floor has at any time existed. In that part of the ruin about the covered passage-way, the walls are complicated, and the plan can hardly be made out, while the curved wall enclosing the apartment *e* is totally overthrown.

In digging among the *débris* with our hammers, we came upon a large earthen vessel at *h*, and shortly afterward discovered another near *i*. They were so situated in a small recess under the sheltering walls that the falling rubbish had not reached them. Roughly-hewn stone lids were fitted carefully over the tops, but both were empty. One had been slightly broken about the rim, while the other had been pierced on the under side by some sharp instrument, and had been mended by laying a small fragment of pottery over the aperture on the inside and cementing it down with clay. They are of the ordinary corrugated pottery, and have a capacity of about three gallons.

Beneath the vessels, spread out on the floor, was a large piece of rush-

matting, and beneath this a quantity of fine vegetable tissue from the interior bark of some kind of tree. The vessels are illustrated in Plate XLIV, and the matting in Plate XLVI.

The rock-face between this ruin and the one above is smooth and vertical, but by passing along the ledge a few yards to the left a sloping face was found, up which a stairway of small niches had been cut; by means of these, an active person, unencumbered, can ascend with safety. On reaching the top, one finds himself in the very doorway of the upper house (*a*, Figure 2) without standing room outside of the wall, and one can imagine that an enemy would stand but little chanceof reaching and entering such a fortress if defended, even by women and children alone. The position of this ruin is one of unparalleled security, both from enemies and from the elements. The almost vertical cliff descends abruptly from the front wall, and the immense arched roof of solid stone projects forward 15 or 20 feet beyond the house (see section, Figure 3). At the right the ledge ceases, and at the left stops short against a massive vertical wall. The niche-stairway affords the only possible means of approach.

The house occupies the entire floor of the niche, which is about 120 feet long by 10 in depth at the deepest part. The front wall to the right and left of the door-way is quite low, portions having doubtless fallen off. The higher wall, *f g*, is about 30 feet long, and from 10 to 12 feet high, while a very low rude wall extends along the more inaccessible part of the ledge, and terminates at the extreme right in a small enclosure, as seen in the plan at *c*.

In the first apartment entered, there were evidences of fire, the walls and ceiling being blackened with smoke. In the second, a member of the party, by digging in the rubbish, obtained a quantity of beans, and in the third a number of grains of corn, hence the names given. There are two small windows in the front wall, and door-ways communicate between rooms separated by high partitions.

The walls of these houses are built in the usual manner, and average about a foot in thickness.

The upper house seems to be in a rather unfinished state, looking as if stone and mortar had run short. When one considers that these materials must have been brought from far below by means of ropes, or carried in small quantities up the dangerous stairway, the only wonder is that it was ever brought to its present degree of finish.

Figure 3 is given for the purpose of making clear the geologic conditions that give shape to the cliffs as well as to show the relations of these houses to the cliffs. The hard and massive beds of rock resist the erosive agents; the soft and friable beds yield, hence the irregularity—the overhanging cliffs, the niches, and benches. *a* is a section of the lower house, *b* of the upper.

It has heretofore been supposed that the occupants of these houses obtained water either from the river below or from springs on the mesa above; but the immense labor of carrying water up these cliffs, as well as the impossibility of securing a supply in case of a siege, made me suspect the existence of springs in the cliffs themselves. In three or four cases these springs have been found, and it is evident that with a climate a very little more moist than the present, a plentiful supply could be expected. Running water was found within a few yards of the group of houses just described, and Mr. Brandegee observed water dripping down the cliffs near a group of small houses on the opposite side of the cañon.

About one mile farther up the cañon, I came upon the ruin photo-

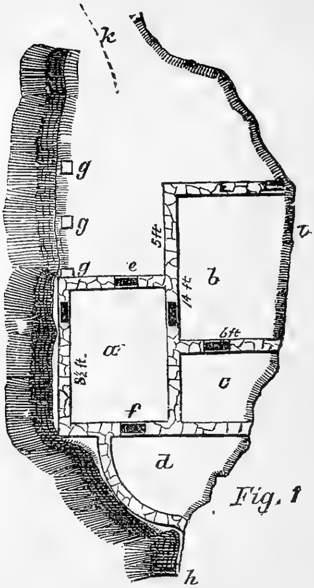


Fig. 1

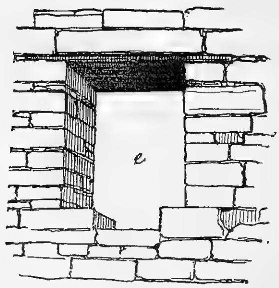


Fig. 2.

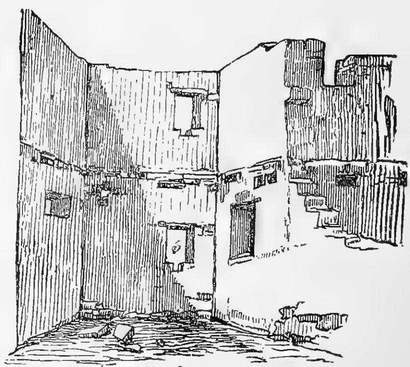


Fig. 3

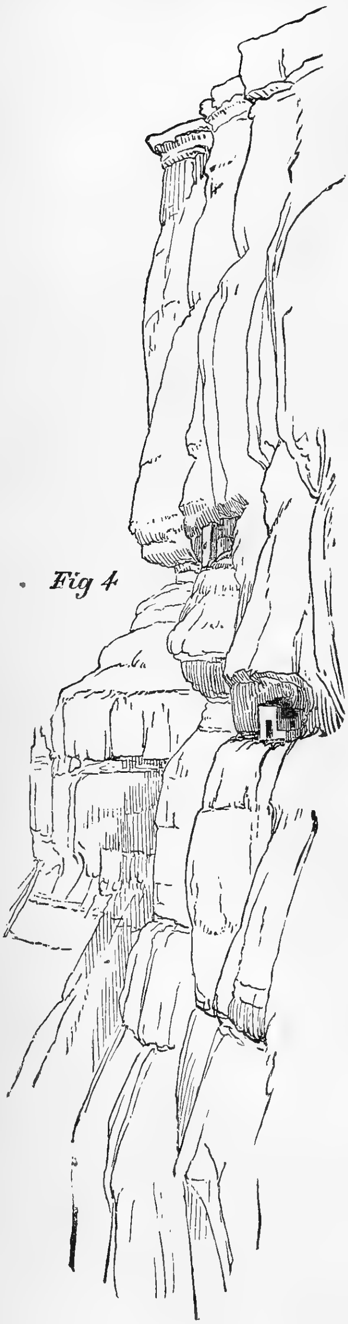


Fig 4

graphed by Mr. Jackson in 1874, and minutely described by him as the two-story cliff-house of the Rio Mancos. It is also in the cliffs of the north side, about 700 feet above the river, and although not so large or complicated in design as the house just described, it shows higher skill in construction and is in a better state of preservation. It is also exceedingly difficult of access. It seems hardly necessary for me to enter into a detailed description, as little can be added to what has already been published;* but for the purpose of having as much of the matter together as possible I present Plate XXXVIII, illustrating some of the interesting features of this house.

Figure 1 gives the ground-plan, and shows the position of the house in relation to the floor of the niche. There are four small apartments only; the front one, *a*, being 10 feet long by 6 wide. Of the back rooms, one is 9 by 10 and the other 6 by 6 feet, while the apartment with the curved wall is much smaller. The walls are about twelve feet high and reach within from 2 to 3 feet of the overhanging roof. They are built in the ordinary manner of stone and adobe mortar, and what is rather remarkable are plastered both inside and out. This plaster does not differ greatly from the common mortar, is lightly spread over the walls, probably with the hands, and in color imitates very closely the hues of the surrounding cliffs, a pleasing variety of red and yellow grays. Whether this was intended to add to the beauty of the dwelling or to add to its security by increasing its resemblance to the surrounding cliffs, I shall not attempt to determine.

Another remarkable feature of this house is the consummate skill with which the foundations are laid upon and cemented to the sloping and overhanging faces of the ledge. The buttresses *b*, *b*, which have probably at one time supported a superstructure of wood or stone, now totally obliterated, are most striking illustrations of this; and just here is a fact that has an interesting bearing upon the question of the antiquity of this structure. These wall-supports or buttresses have originally been four in number, one evidently having fallen off, and are built in continuation of the front wall, on a smooth sloping surface of rock. Now, the sandstone of which this rounded slope is composed is rather coarse and soft, and hence easily disintegrated. It is here also not greatly protected from the weather, since the cliffs above do not overhang to any extent, and must, year by year, yield a little to the elements; but I observe that since the construction of these foundations no perceptible change has taken place; the thickness of a sheet of paper has hardly been washed from the surface of the rock, and the mortar, which is of almost equal firmness with the rock, lies upon it as if placed there within a dozen years, and the appearance of the plaster on the outer wall, although somewhat cracked and broken off, does not add greatly to our impressions of their antiquity.

There is also a fact worthy of notice in regard to the question of occupancy. I have already stated my impression that these houses were not used as constant dwelling-places, but rather as places of occasional resort. I notice that, although the building seems complete and has had its floors laid and its door-ways and windows conveniently and carefully arranged, the plastering of the interior is almost untouched, that with the exception of three names scratched in the soft, thick coat of adobe by Mr. Jackson's party, there is almost no trace of the presence of man; yet this plaster may have been applied only shortly before the final desertion, and hence no definite conclusion can be drawn.

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*Bulletin No. 1, second series, p. 20.

A sketch of one of the door-ways is given in Figure 2. The outline is accurately drawn, but there is a little too much regularity in the stone-work. It will be seen that the aperture is of very nearly the same width above and below, which is rather unusual, since, in these ruins, as well as in those farther south, the door-ways and windows are, as a rule, narrower at the top. This drawing also shows the manner of employing a number of small straight beams of wood as lintels, for the purpose, evidently, of strengthening the masonry above.

There are two of these exterior door-ways only, one opening into each story of the front room from the unoccupied part of the niche; these are shown in Figure 3, a sketch of the interior of the front room taken from the side *f*. There is only a low wall between this room and the room *c*, while small door-ways communicate with the other apartments. There is a small rectangular window, 22 inches high by 30 wide, in the front wall, from which a fine view can be had of the deep narrow valley below.

Figure 4 is designed to show the extraordinary situation of these houses. Whether viewed from below or from the heights above, the effect is almost startling, and one cannot but feel that no ordinary circumstances could have driven a people to such places of resort.

There are no ruins of importance in the cañon of the Mancos above the two-story house. Indistinct remains occur on the bottoms in a number of places, and a few small houses were observed in the cliffs. The most interesting of these is built upon a ledge about 40 feet above the trail, and is nearly midway between the two-story house and the head of the cañon. It does not differ in any essential point from the ruins already described. I shall therefore pass it by, in order to take up two very interesting groups of ruins that occur about 20 miles to the northwest.

Between the Mesa Verde and the Late Mountains, of which Ute Peak is the culminating summit, there is a long, deep valley or strip of lowland that connects the great lowland of the Lower Mancos with the cañon-cut plain that rises toward the Dolores. The southern end of this depressed strip drains into the Mancos, the northern into the McElmo. The latter stream heads along the north base of the Mesa Verde within five miles of the Mancos at the point were it enters the cañon, and flows westward, passing along the north base of Ute Mountain, curving around to the southwest and reaching the San Juan nearly 10 miles beyond the Utah line. The large depressed area drained by this stream contains a great number of ruins, many of which have not yet been examined.

PLATE XXXIX.—THE TRIPLE-WALLED TOWER.

The group partially illustrated in this plate is situated on a low bench within a mile of the main McElmo, and near a dry wash that enters that stream from the south. It seems to have been a compact village or community-dwelling, consisting of two circular buildings and a great number of rectangular apartments. The circular structures or towers have been built, in the usual manner, of roughly-hewn stone, and rank among the very best specimens of this ancient architecture. The great tower is especially noticeable on account of the occurrence of a third wall, as seen in the drawing and in the plan at *a*. In dimensions it is almost identical with the great tower of the Rio Mancos. The walls are traceable nearly all the way round, and the space between the two outer ones, which is about 5 feet in width, contains fourteen apart-

Fig. 1

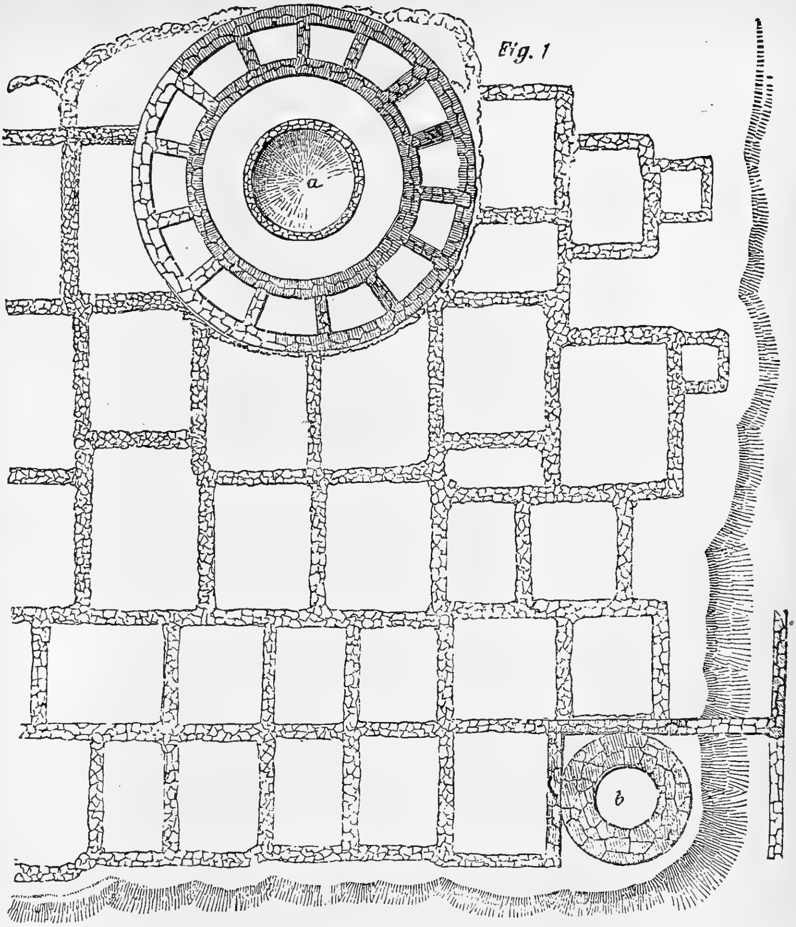
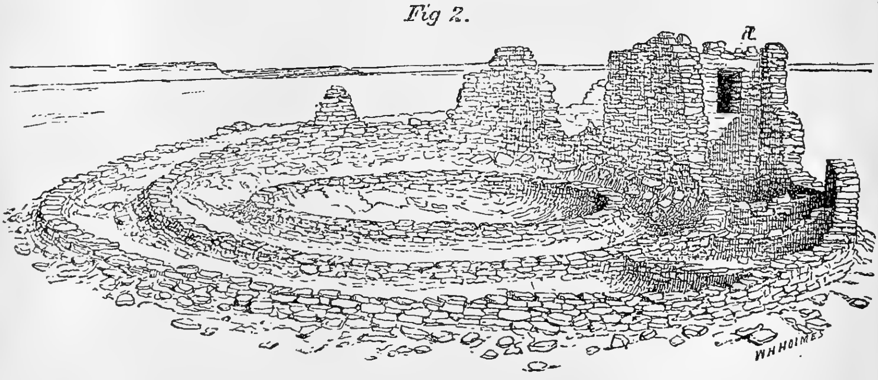
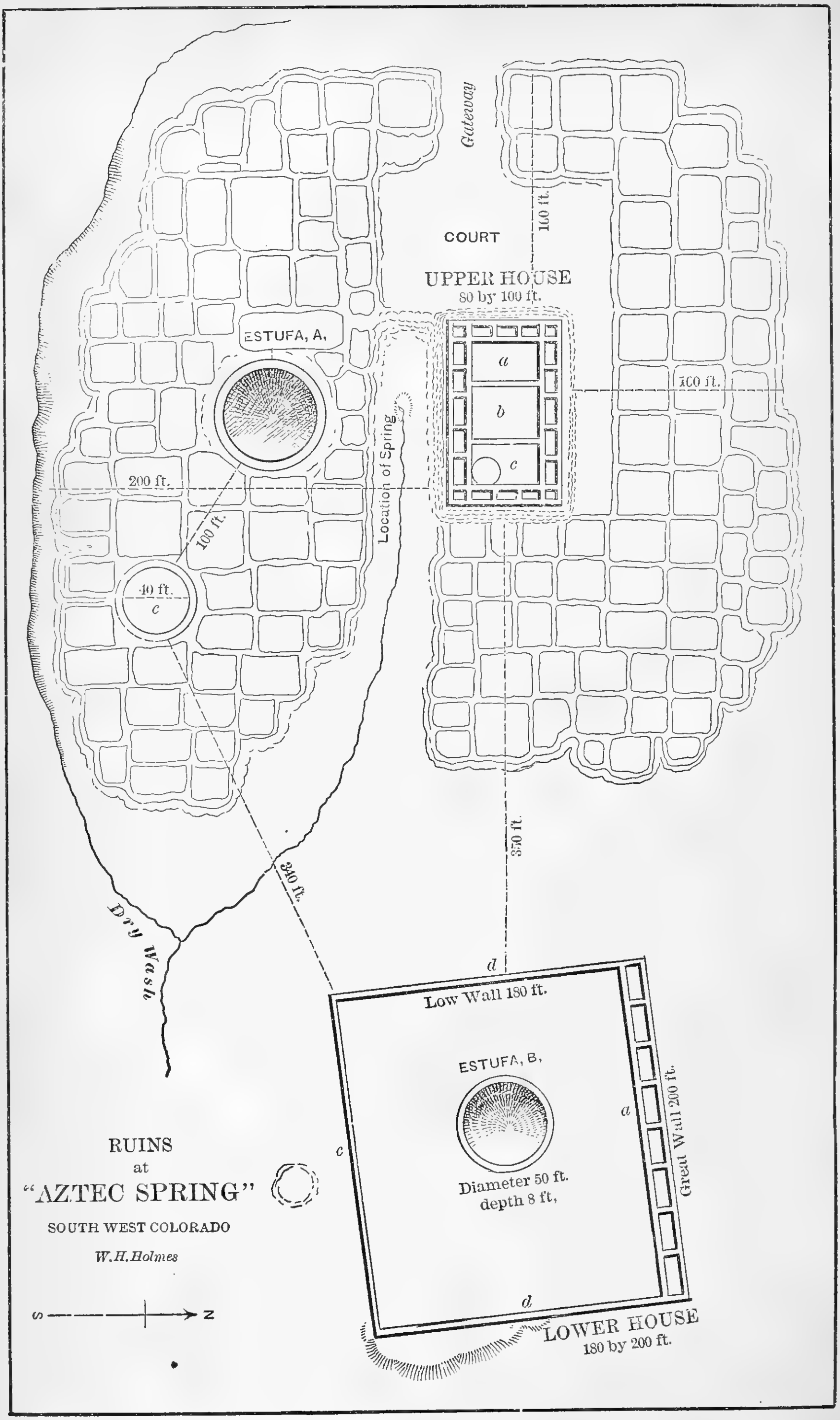


Fig 2.





Gateway
COURT
160 ft.
UPPER HOUSE
80 by 100 ft.
ESTUFA, A,
a
b
c
100 ft.
Location of Spring
200 ft.
100 ft.
40 ft.
c
350 ft.
340 ft.
Dry Wash
d
Low Wall 180 ft.
ESTUFA, B,
Diameter 50 ft.
depth 8 ft,
a
Great Wall 200 ft.
c
d
LOWER HOUSE
180 by 200 ft.
RUINS
at
"AZTEC SPRING"
SOUTH WEST COLORADO
W.H.Holmes
S
N

ments or cells. The walls about one of these cells are still standing to the height of 12 feet; but the interior cannot be examined on account of the rubbish which fills it to the top. No openings are noticeable in the circular walls, but door-ways seem to have been made to communicate between the apartments; one is preserved at *d*.

The inner wall has not been as high or strong as the others, and has served simply to enclose the *estufa*. This tower stands back about one hundred feet from the edge of the mesa and near the border of the village. The smaller tower, *b*, stands forward on a point that overlooks the shallow gulch; it is 15 feet in diameter; the walls are 3½ feet thick and 5 feet high on the outside. Beneath this ruin, in a little side gulch, are the remains of a wall 12 feet high and 20 inches thick. The remainder of the village is in such a state of decay as to be hardly traceable among the artemisia and rubbish. The apartments number nearly a hundred, and seem, generally, to have been rectangular. They are not, however, of uniform size, and certainly not arranged in regular order. The walls are marked by low lines of loose rubble which show no stone in place, and I am inclined to believe that they have never been raised to any great height. It is not impossible that they have been, originally, of a species of rubble-masonry such as is seen in some of the great *casas* farther south, and that these meagre remains are all that is left of an imposing structure, but the total want of regularity both in the form and size of the apartments seems inconsistent with such a conclusion. In reality they are more like a cluster of pens such as are used by the Moqui tribes for the keeping of sheep and goats. The site of this village can hardly have been chosen on account of its defensive advantages, nor on account of the fertility of the surrounding country. The neighboring plains and mesas are as naked and barren as possible. The nearest water is a mile away, and during the drier part of the season the nearest running water is in the Rio Dolores, nearly fifteen miles away. To suppose an agricultural people existing in such a locality, with the present climate, is manifestly absurd. Yet every isolated rock and bit of mesa within a circle of miles is strewn with remnants of human dwellings.

PLATE XL.—RUINS AT "AZTEC SPRINGS."

Another very important group of ruins is located in the depression between the Mesa Verde and the Late Mountains, and near the divide between the McElmo and Lower Mancos drainage. It is stated by Captain Moss and others who have been in this locality that up to within two or three years there has been a living-spring at this place, and the spot has been christened by them Aztec Springs.

The site of the spring I found, but without the least appearance of water. The depression formerly occupied by it is near the centre of a large mass of ruins, similar to the group last described, but having a rectangular instead of a circular building as the chief and central structure. This I have called the *upper house* in the plate, and a large walled enclosure a little lower on the slope I have, for the sake of distinction, called the *lower house*.

These ruins form the most imposing pile of masonry yet found in Colorado. The whole group covers an area of about 480,000 square feet, and has an average depth of from 3 to 4 feet. This would give in the vicinity of 1,500,000 solid feet of stone-work. The stone used is chiefly of the fossiliferous limestone that outcrops along the base of the Mesa

Verde a mile or more away, and its transportation to this place has doubtless been a great work for a people so totally without facilities.

The upper house is rectangular, measures 80 by 100 feet, and is built with the cardinal points to within five degrees. The pile is from 12 to 15 feet in height, and its massiveness suggests an original height at least twice as great. The plan is somewhat difficult to make out on account of the very great quantity of *débris*.

The walls seem to have been double, with a space of 7 feet between; a number of cross-walls at regular intervals indicate that this space has been divided into apartments, as seen in the plan.

The walls are 26 inches thick, and are built of roughly-dressed stones, which were probably laid in mortar, as in other cases.

The enclosed space, which is somewhat depressed, has two lines of *débris*, probably the remains of partition-walls, separating it into the three apartments, *a*, *b*, *c*. Enclosing this great house is a net-work of fallen walls, so completely reduced that none of the stones seem to remain in place; and I am at a loss to determine whether they mark the site of a cluster of irregular apartments, having low, loosely-built walls, or whether they are the remains of some imposing adobe structure built after the manner of the ruined pueblos of the Rio Chaco.

Two well-defined circular enclosures or *estufas* are situated in the midst of the southern wing of the ruin. The upper one, *A*, is on the opposite side of the spring from the great house, is 60 feet in diameter, and is surrounded by a low stone wall. West of the house is a small open court, which seems to have had a gate-way opening out to the west, through the surrounding walls.

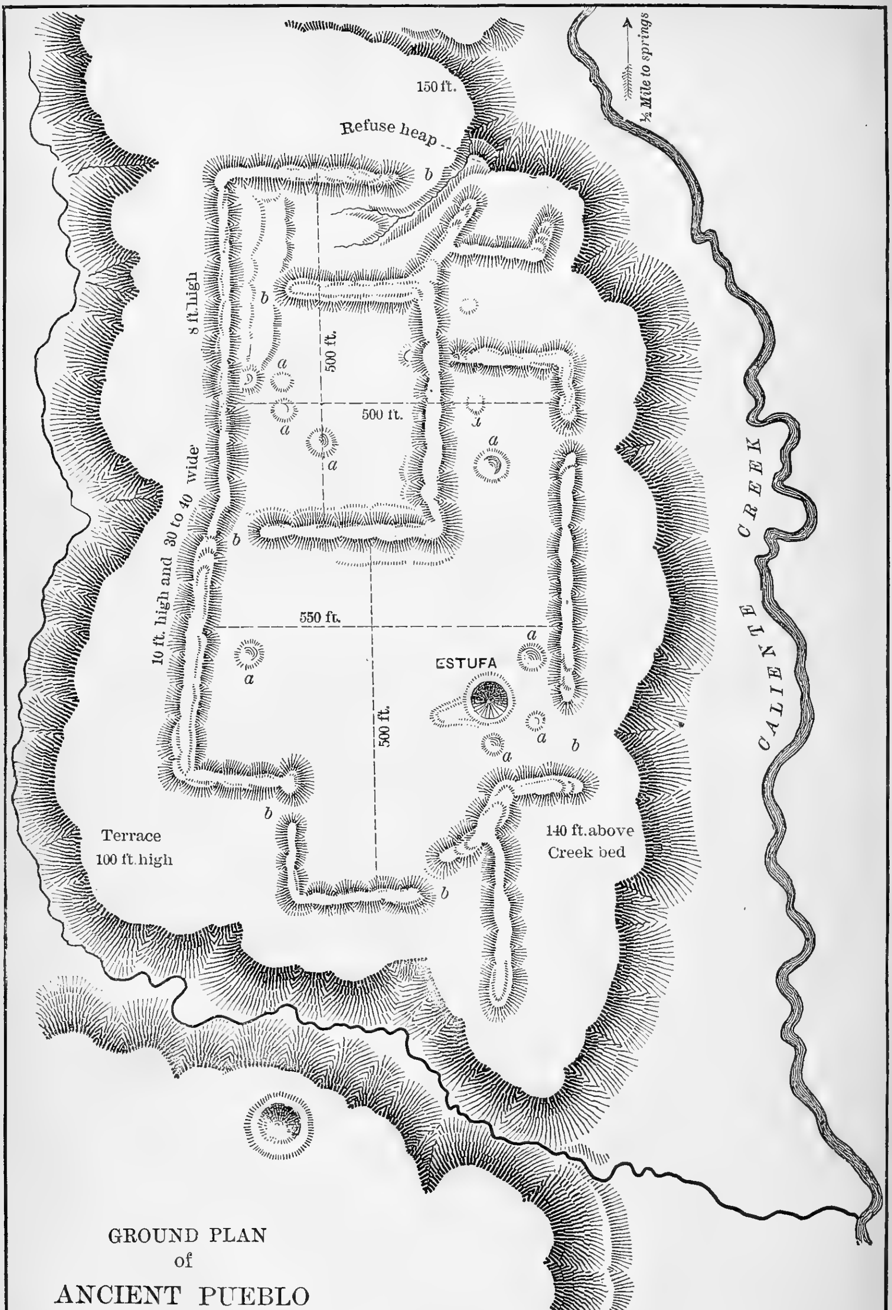
The lower house is 200 feet in length by 180 in width, and its walls vary fifteen degrees from the cardinal points. The northern wall, *a*, is double, and contains a row of eight apartments about 7 feet in width by 24 in length. The walls of the other sides are low, and seem to have served simply to enclose the great court, near the centre of which is a large walled depression (*estufa B*). No other ruins were observed in the neighborhood of these, although small groups are said to exist along the base of the Late Mountains, a few miles to the southwest.

The dry, sloping plain between the Mesa Verde and the Rio Dolores seems also to have been a favorite resort of the town-building tribes. Numerous ruins occur along the borders of the cañons that drain into the McElmo, and especially near the heads of these cañons where springs usually occur.

At the south bend of the Dolores there are a great number of ruins, many of which compare favorably with the lowland ruins farther south. Dr. Newberry passed through this region in 1859, and his report* gives a brief description of a few of these remains.

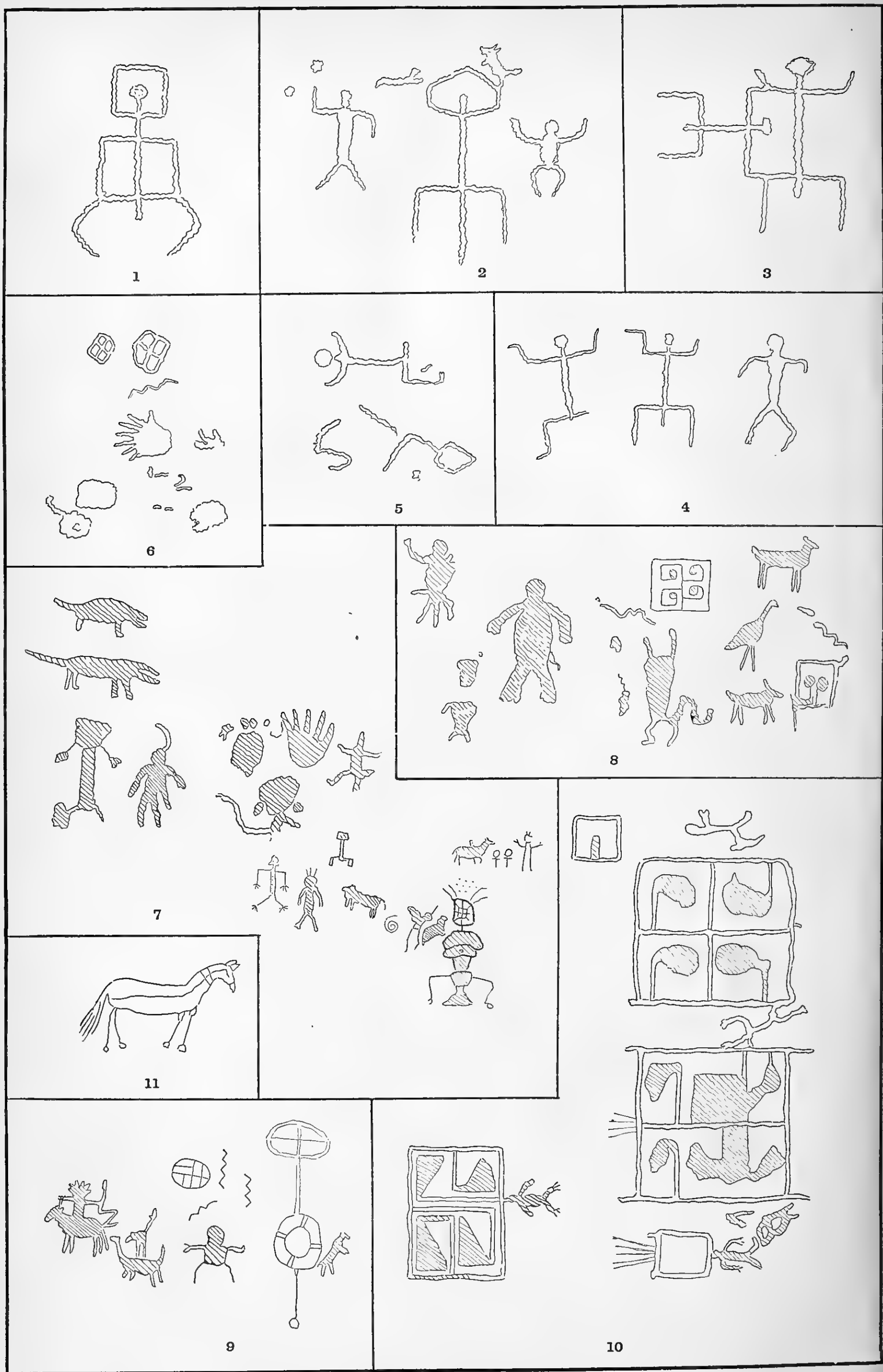
I made a hasty examination of such of the groups as I had an opportunity to visit, but had no time to make plans. Other ruins, including the remains of a large circular enclosure, occur on the river-bottom about two miles below the bend. I also noticed the small cliff-houses mentioned by Dr. Newberry, but did not visit them. West of the Do-

* Macomb's expedition to the junction of the Grand and Green rivers, Washington, 1876. Dr. Newberry says: "The hill from which I obtained this view is crowned with an extensive series of very ancient ruins. The principal one is a pueblo, nearly 100 feet square, once substantially built of dressed stone, now a shapeless heap, in which the plan of the original structure can, however, be traced. Like most of the ruined pueblos of New Mexico, it consisted of a series of small rooms clustered together like cells in a bee-hive. Near the principal edifice are mounds of stone, representing subordinate buildings. Among these are numerous large depressions marking the places of cisterns or *estufas*."



GROUND PLAN
of
ANCIENT PUEBLO
at
OJO CALIENTE
NEW MEXICO.

W H Holmes.



Russell & Struthers N.Y.

lores our party was compelled to make very rapid marches, and I found it impossible to turn out of the trail long enough to make a satisfactory study of the ruins that occur by the way.

At one locality which I took to be Surouara* there appeared on our left a very extensive series of ruins, and it was a sore disappointment to be compelled to pass by without even a halt.

About the sources of the Hovenweep and Montezuma creeks there are occasional ruins of no great importance. In the vicinity of the Sierra Abajo I found no traces of ancient occupation further than a few arrow-points and fragments of chipped quartzite. Little or no trace of ancient occupation was observed north of a line between the Sierra Abajo and main peaks of the La Plata Mountains.

A very large and interesting ruin† occurs on the Animas River, near the southeast corner of our district for 1875, which seems to bear a very close relationship in its architecture to the ruins of the Rio Chaco. Unfortunately, no plans of this ruin have been made.

PLATE XLI.—RUIN AT OJO CALIENTE, NEW MEXICO.

For the sake of comparison, I present in Plate XLI the ground-plan of a ruined pueblo found at Ojo Caliente, New Mexico. It occurs on a high, almost isolated fragment of terrace near Caliente Creek. It has been constructed chiefly of adobe, and has consisted of rows of apartments surrounding a number of large open courts. Individual walls cannot be traced, and the rows of houses are reduced to smooth rounded ridges of earth. These are indicated on the plan, and are often as much as 8 feet high, and 30 feet wide at the base. The courts contain a number of small circles or mounds, *a*, *a*, and the single *estufa* is identical in appearance with those among the ruins of Colorado. A number of openings, *b*, *b*, through the walls indicate the location of gate-ways. *Metates*, arrow-heads, and many fragments of pottery were found. Many other groups of ruins similar to this occur in this as well as in the neighboring valleys. Near Abiquiu a large pueblo occurs, at which I found a stone axe and a number of arrow-heads and *metates*. A couple of skeletons were also obtained here. This ruin is described at length by Dr. Yarrow in his report for 1874.‡

PLATES XLII AND XLIII.

Although it is quite impossible to read the curious rock-inscriptions of unknown tribes, it is conceded that in most cases they have a meaning and represent an idea or record an event. Aside from this, however, they are valuable to the historian as records of the grade of civilization reached by the tribes who executed them.

That the examples given in the two following plates belong to the age of the cliff-builders cannot be satisfactorily proved, but, at the same

* Of these ruins Dr. Newberry says: "The houses are, many of them, large, and all of them built of stone, hammer-dressed on the exposed faces. Fragments of pottery are exceedingly common, though, like the buildings, showing great age. There is every evidence that a large population resided here for many years, perhaps centuries, and that they deserted it several hundred years ago; that they were Pueblo Indians, and hence peaceful, industrious, and agricultural. * * * The ruins of several large reservoirs, built of masonry, may be seen at Surouara, and there are traces of *aciquias*, which led to these, through which water was brought, perhaps, from a great distance."

† See Dr. Endlich's report, Annual Report of United States Geological Survey, for 1875, p. 177; also, Mr. Rhoda's report, p. 240. See also Dr. Newberry's Report, Expedition to the Junction of Grand and Green Rivers, p. 80.

‡ Report of the Chief of Engineers for 1875, p. 1064.

time, evidence that they do is not wanting. Some are found on the cliffs and in the niches with the cliff-dwellings, while all are in localities that must have been frequently visited by these people. Some are found in the cañon of the Mancos, others on the bluffs of the San Juan, and many in the cañons farther west.

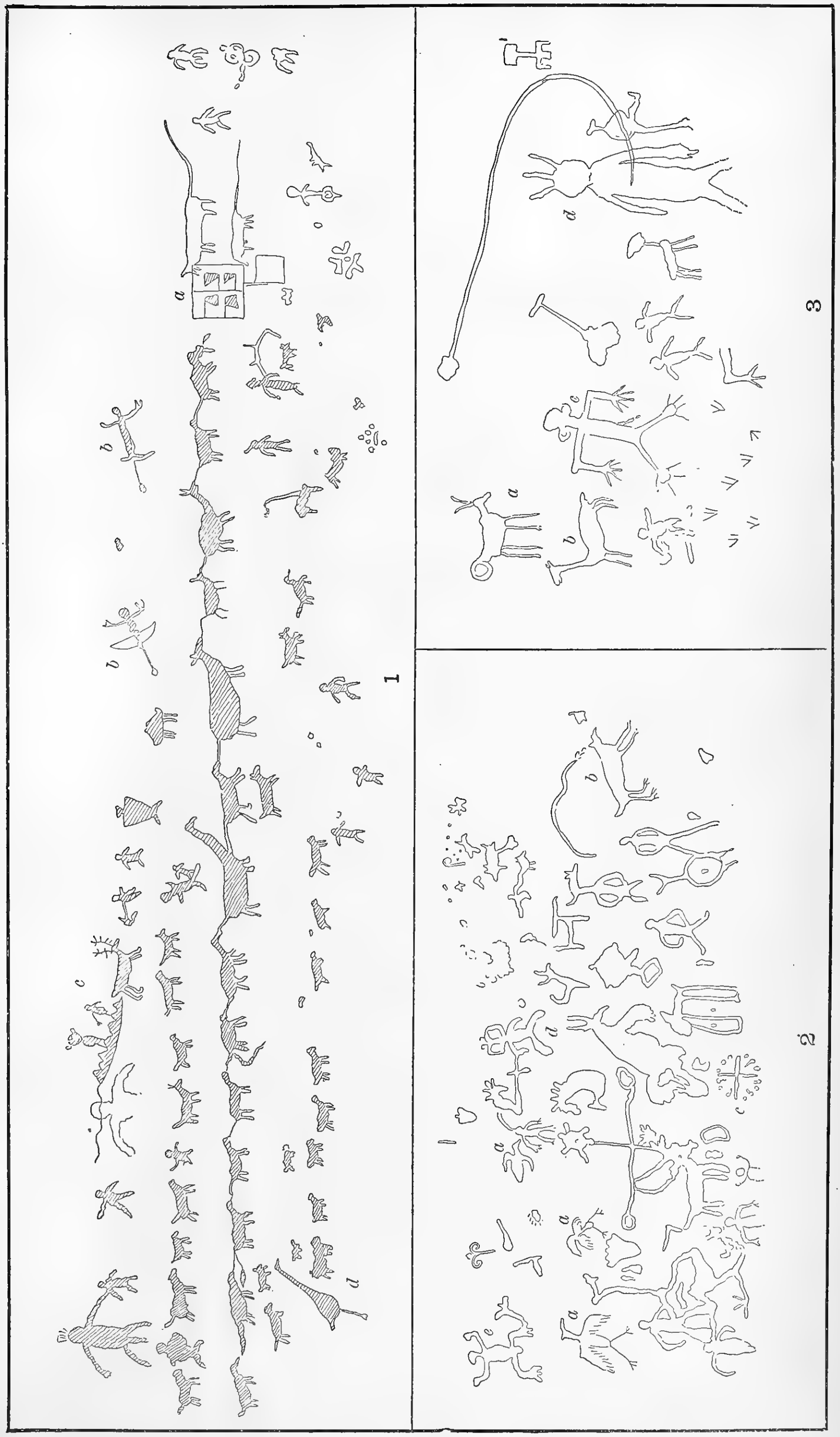
Figures 1, 2, and 3, Plate XLII, occur on the Mancos near the group of cliff-houses figured in Plate XXXVI. They are chipped into the rock, evidently by some very hard implement, and rudely represent the human figure. They are certainly not attempts to represent nature, but have the appearance rather of arbitrary forms designed to symbolize some imaginary being.

Figures 4, 5, and 6 were found in the same locality, not engraved, but painted in red and white clay upon the smooth rocks. These were certainly done by the cliff-builders, and probably while the houses were in process of construction, since the material used is identical with the plaster of the houses. The sketches and notes were made by Mr. Brandegee. The reproduction is approximately one-twelfth the size of the original.

The examples given in Figures 7, 8, 9, 10, and 11, as well as those in Plate XLIII, occur on the Rio San Juan about 10 miles below the mouth of the Rio La Plata. A low line of bluffs, composed of light-colored massive sandstones, that break down in great smooth-faced blocks, rises from the river-level and sweeps around toward the north. Each of these great blocks has offered a very tempting tablet to the graver of the primitive artist, and many of them contain curious and interesting inscriptions. Drawings were made of such of these as the limited time at my disposal would permit. They are all engraved or cut into the face of the rock, and the whole body of each figure has generally been chipped out, frequently to the depth of one-fourth or one-half an inch.

The work on some of the larger groups has been one of immense labor, and must owe its completion to strong and enduring motives. With a very few exceptions the engraving bears undoubted evidence of age. Such new figures as occur are quite easily distinguished, both by the freshness of the chipped surfaces and by the designs themselves. Figure 11 gives a specimen of the modern work; it is evidently intended to represent a horse, and is done in the manner of the Navajoes. It will readily be seen that among all the figures given of the ancient work there is no animal that resembles a horse, and we can hardly suppose that artists who could so cleverly delineate birds and deer and men, would fail in an attempt to represent an animal of so marked a character. The curious designs given in Figure 10 have a very perceptible resemblance to many of the figures used in the embellishment of pottery.

The most striking group observed is given in Figure 1, Plate XLIII. It consists of a great procession of men, birds, beasts, and fanciful figures. The whole picture as placed upon the rock is highly spirited, and the idea of a general movement toward the right, skilfully portrayed. A pair of winged figures hover above the train as if to watch or direct its movements; behind these are a number of odd figures, followed by an antlered animal resembling a deer, which seems to be drawing a notched sledge containing two figures of men. The figures forming the main body of the procession appear to be tied together in a continuous line, and in form resemble one living creature about as little as another. Many of the smaller figures above and below are certainly intended to represent dogs, while a number of men are stationed about, here and there, as if to keep the procession in order.


1
2
3

As to the importance of the event recorded in this picture no conclusions can be drawn; it may represent the migration of a tribe or family or the trophies of a victory. A number of figures are wanting in the drawing at the left, while some of those at the right may not belong properly to the main group. The reduction is, approximately, to one-twelfth.

Figures 2 and 3 of the same plate represent only the more distinct portions of two other groups. The complication of figures is so great that a number of hours would have been necessary for their delineation, and an attempt to analyze them here would be fruitless.

POTTERY.

The pottery of the ancient tribes of the San Juan Valley is undoubtedly superior in many respects to that of the town-building tribes of to-day. It is especially superior in composition and surface-finish. In form and ornamentation it does not compare well with the highly artistic wares of the Moquois and Zunis. There is great similarity, however, in every respect, and the differences do not seem greater than could be expected in the manufactures of the same people at periods separated by a few generations, or even of related tribes of the same time surrounded by different physical features or by different neighbors.

The study of the fragmentary ware found about the ruins is very interesting, and its immense quantity is a constant matter of wonder. On one occasion, while encamped near the foot of the Mancos Cañon, I undertook to collect all fragments of vessels of manifestly different designs within a certain space, and by selecting pieces having peculiarly marked rims I was able to say with certainty that within 10 feet square there were fragments of fifty-five different vessels. In shape these vessels have been quite varied, but by far the greater portion have been of the form of bowls and handled cups or ladles. Jugs and vases also occur. In general the forms have been so simple that with the aid of the great quantities of fragments it is not difficult, providing the rim is preserved, to say with accuracy to what form of vessel a given specimen belongs. The bottoms of the various vessels, excepting a kind of handled mug, are rounded or very slightly flattened.* The art of ornamentation seems to have been especially cultivated, as very few specimens are found that are not painted, indented, or covered with raised figures. Indeed, these ornamental designs are often so admirable, and apparently so far in advance of the art-ideas of these people in other respects, that one is led to suspect that they may be of foreign origin. But there is certainly no conclusive evidence that these people ever came in contact with Europeans or were even influenced by European art.

The material used in the manufacture of pottery was generally a fine clay (in which the country abounds), tempered with sand or pulverized shells. The modelling was done almost exclusively with the hand; no wheel has been used, and no implement whatever, except for surface creasings or indentings.

The thickness of the ware varies from $\frac{1}{8}$ to $\frac{1}{2}$ an inch. Lightness has evidently been greatly desired, and vessels having a capacity of many gallons are not more than $\frac{1}{4}$ of an inch thick in any part.

* Dr. Charles Rau says, in an article on Indian pottery, in the Smithsonian Report for 1866, p. 346, that "the oldest vessels of all nations who practised the potter's art probably exhibited that shape (the rounded bottom), the model of which was furnished by nature in the gourd and other fruits presenting rounded outlines. A flat bottom, therefore, would denote a progress in the ceramic art."

Nearly all of the vessels and fragments collected have been baked or burned, but not to such a degree as to greatly change the color of the clay.

Most, if not all, of the painted pottery has received a thin coating of some mineral solution that gives a beautiful enamel-like surface, not greatly inferior in hardness to the vitreous glazing of our potters. Upon this surface, before burning, the color is laid, apparently with a brush. In one or two cases the indented ware has a light gray surface coating that on the broken edges has quite a perceptible thickness.

A specimen collected at Ojo Caliente, New Mexico, has been coated with a thin film of finely-powdered mica. This specimen has been ornamented by a series of slight grooves in a manner similar to much of the pottery found in the Mississippi Valley. In the entire collection there is but one specimen that shows evidence of having been formed in a basket. It was found in the lower part of the San Juan Basin.

A few specimens are covered with painted figures on the inside, and have also thumb indentations on the outside.

Fragmentary pottery, of the same character as that collected in the San Juan Valley, has been collected by government expeditions over an immense area to the south and west. By far the richest find was that made by Dr. E. Palmer at Saint George, Utah. The greater part of the collection made is now in the Government Museum. I have therefore been able to compare them with our own specimens, and find them almost identical in every respect.

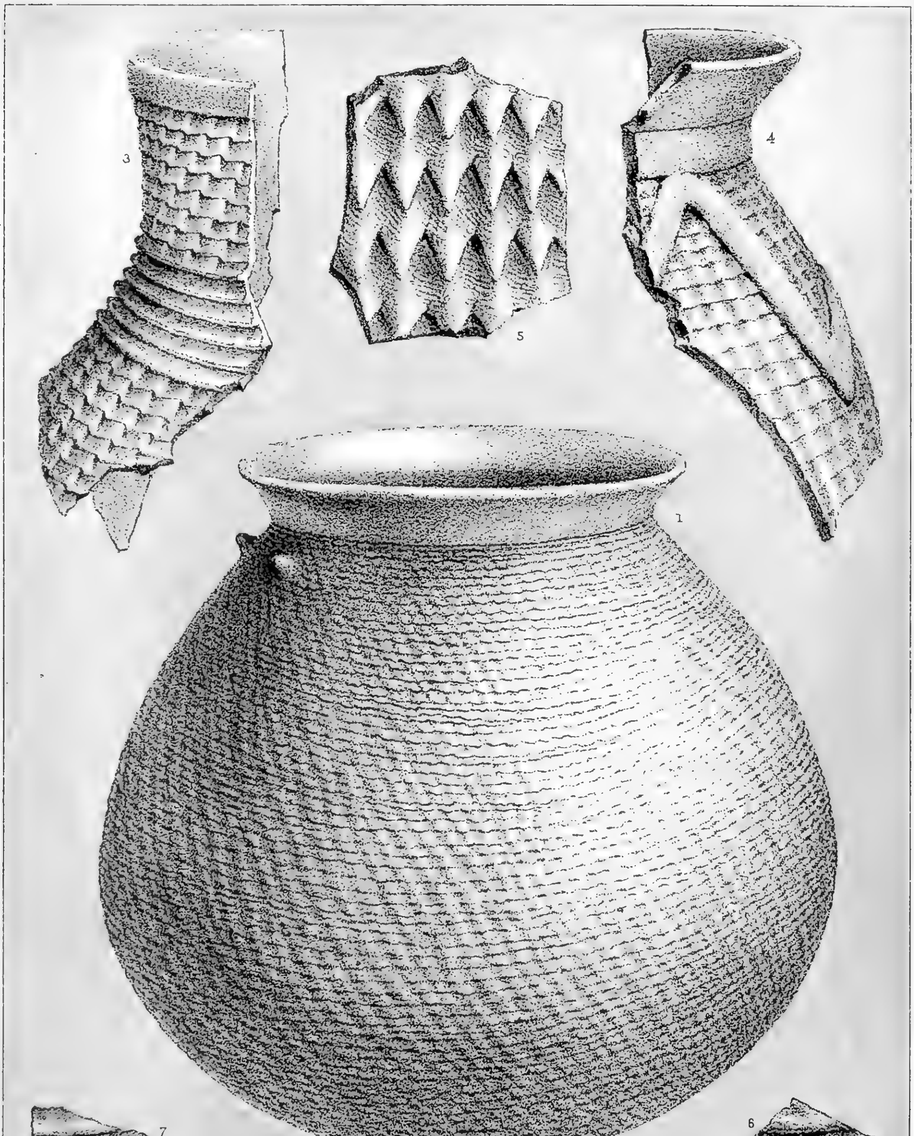
Cuts of a large number of specimens are given by Mr. Ewbank in Vol. III, Pacific Railroad Report. They are chiefly from Zuni and the Colorado Chiquito, and seem to present no features differing from the more northern examples. Lieutenant Simpson also gives a number of specimens in color in his report on "An Expedition to the Navajo Country."

In order to give to those who have no opportunity to examine and compare for themselves the various specimens of the ancient ware as complete an idea of its appearance as possible, I have made a number of restorations. The forms given are not in any sense imaginary, as there are fragments in great numbers that illustrate every part of the different vessels presented; besides, there are entire specimens at hand of every form given. I have restored from such small fragments simply because they happen to contain more elaborately-painted designs than any of the entire vessels. The peculiarities of the various varieties in form and color can be described more readily in connection with the examples given in the plates.

PLATE XLIV.

This plate is intended to illustrate the corrugated and indented ware. Heretofore specimens of this class have been quite rare, as it is not made by any of the modern tribes.

Figure 1 represents one of a pair of large vessels exhumed from the ruins of the "sixteen-windowed" cliff-house of the Rio Mancos. It has a capacity of about three gallons, and was probably used for carrying or keeping on hand a supply of water. It is quite light, not weighing more than a common wooden pail, and is made of a light-gray clay tempered with coarse sand, and but slightly burned. The corrugated appearance is given by laying on strips of clay, in somewhat regular succession, and pressing them into place and indenting them with the thumb or a stick. Whether a thin shell of clay is first constructed and the strips laid on and pressed down so as to unite with it, or whether



W. H. Holmes, del. & lith. T. Sinclair & Son, 1877.

ANCIENT POTTERY.

the vessel is built up by the strips alone, cannot be determined, since the inside is perfectly smooth, excepting finger-marks, and the strips are so welded into the general texture of the vessel that individual strips cannot be detected beneath the surface when examined on broken edges.

In the specimen figured the workman has begun near the centre of the rounded bottom and laid a strip in a continuous but irregular spiral (see Fig. 3) until the rim was reached, indenting the whole surface irregularly with the finger. A smooth recurved rim has then been added in a very skilful manner. Two small conical bits of clay have been set in near the rim, as if for ornament. The companion piece has a small scroll-shaped ornament similarly placed.

Figure 2 shows the manner in which the spiral is started on the bottom of the vessel. In some cases the crimping or indenting begins with the spiral, but in others the strip of clay is left quite smooth for a considerable space, as in the example.

Figure 3 represents a fragment of a large vase or jar obtained by Mr. Jackson in the valley of Epsom Creek, Southeast Utah. The original vessel has had a capacity of at least ten gallons, and has certainly presented a very attractive appearance, as the outline has been quite elegant and the surface-modelling symmetrical and highly artistic. It has been built up in the usual manner of a continuous band or strip of clay, the ornamentation has been varied by leaving occasional belts of the overlapping strips quite plain, while the indentations in the alternating belts have been made with great care, probably with the thumb. The rim is smooth and upright and has a diameter of 9 inches. The neck is narrow and straight, and the body swells to 18 inches at the greatest circumference. The specimen as given does not show this, however, as the lower part has been lost. The inside is smooth; the material is coarse clay, in which can be seen much coarse sand, apparently ground granite, as fragments of both quartz and hornblende appear. For so large a vessel the walls are remarkably thin, not being more than one-fourth of an inch thick in any part.

Figure 4. The vase of which this is a large fragment has been much smaller than the preceding, and of greatly inferior workmanship. It has resembled more closely the specimen given in Figure 1, but is especially noticeable from the attempt at ornament. A festoon-like strip of clay has been laid on beneath the rim.

Figure 5. This is one of the best specimens of raised ornamentation in the collection. It has been modelled entirely with the fingers, and retains perfectly the most delicate markings of the skin. The strips of clay, which run obliquely across the specimen, have been indented, as usual, with the thumb, and the projecting "beads" have been slightly drawn down and pointed by pressure between the fingers. The drawing is nearly natural size.

Figure 6. The modelling of this specimen is hardly inferior to that of the preceding. The strips of clay have been laid on with great care, every other layer, only, being pressed down and indented. It can be seen that each impression of the thumb is clearly defined, and the nail-marks are as distinct as if made yesterday.

Figure 7. This specimen differs from the others given in having been indented with some sharp implement. The clay spiral has been laid on and gently pressed down by the fingers. Afterward an ornamental design has been produced by a series of sharp indentations.

If we should judge by the curvature of these fragments, the complete

vessels have exceeded in size the one given in Figure 1, and must have been for those primitive days master-pieces of the potter's art.

In form, vessels of this class have not been so varied as the painted ware; bowls, cups, and spoons or ladles are not known, but nearly every variety of narrow-necked vessels may be found in collections.

PLATE XLV.

As previously mentioned it is not difficult, when we have such a great number of specimens at hand, to arrive at an accurate idea of the shape of any vessel of which we have ordinarily large fragments. None of the more elaborately ornamented vessels have been preserved entire, and in order to do justice to the artistic abilities of the ancient potters, I give in this plate a few restorations. In preparing the lithograph the tendency is to make the surfaces too smooth and the forms too symmetrical, but we may make allowance for this and still have specimens very little inferior to those figured. As the fragments used are plainly indicated in the drawing, there need be no misunderstanding as to the method employed in making the restorations.

Figure 1 represents a bowl which, as the fragments indicate, has been decorated with beautiful designs in black both inside and out. The original has been about 6 inches in diameter and 4 inches deep.

Figure 2. This bowl has been about twice the size of the above, and has contained ornamental designs of a somewhat more intricate pattern.

Figure 3. Is restored from a large fragment which has on the inside a design in which the scroll is used. This scroll has been produced by filling in the spaces about it with dark color.

Figure 4. This bowl is entire, and was collected by Mr. Jackson, on the San Juan River, in Utah. It has a capacity of about three pints. The ornamental design is applied to the inside and is quite simple.

Figure 5. Fragments of vessels of this shape were found in many localities. All are covered with ornamental designs similar to those on other vessels. Two entire specimens were obtained by Captain Moss, in a grave on the Rio San Juan.

Figure 6. The fragment from which this form is drawn was found on the Rio San Juan near the Great Creston or Hogback. The enamel is dark, and the painted design has a dark metallic lustre. The upper part of the vessel has been quite handsome in design; the lower part has in all probability been as indicated in the restoration, as all whole specimens which have similarly shaped necks have the bottom round or nearly so.

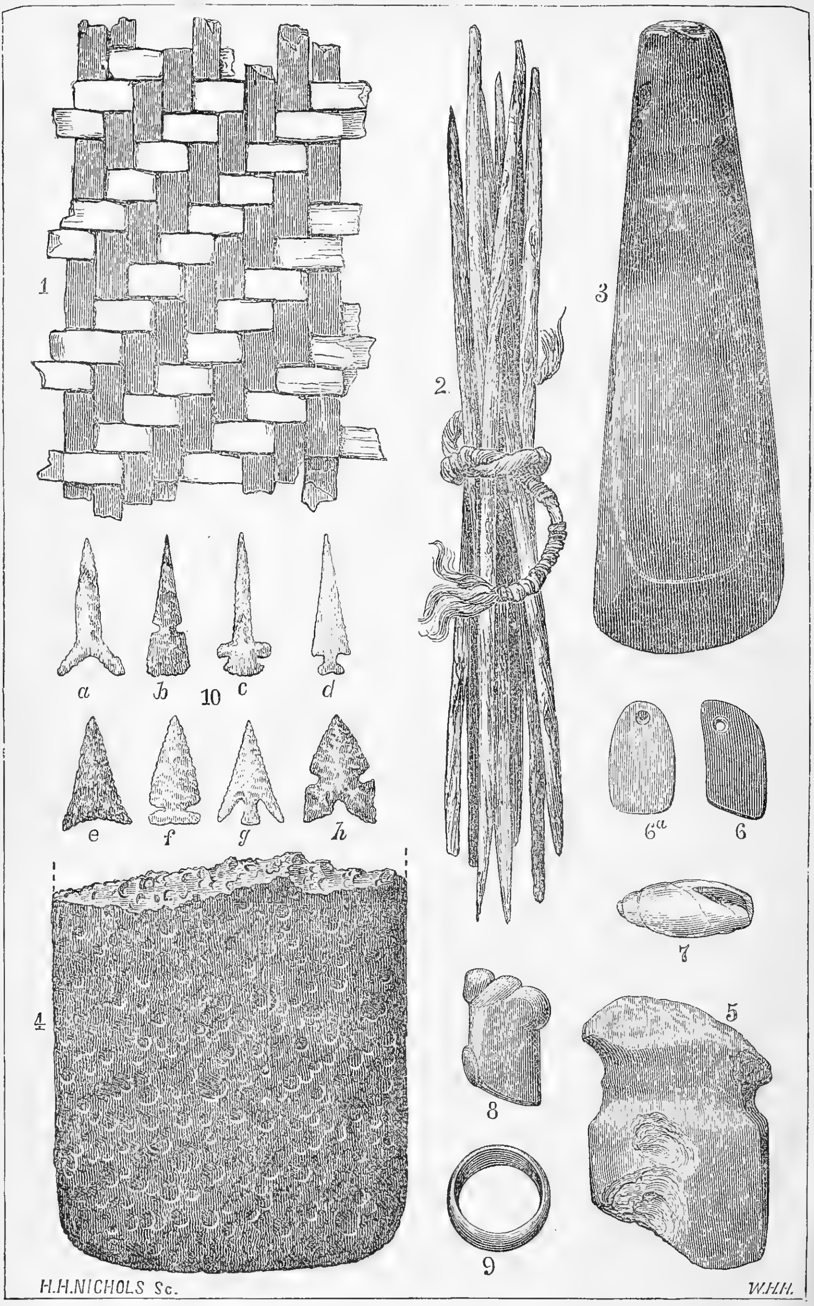
Figure 7. The most striking characteristic of this specimen is the shape of the rim, which has been fashioned for the reception of a lid. The quality of the ware has been good, and the shape seems to have been quite symmetrical. It was found in the same locality as the preceding.

Figure 8. A great many disk-shaped specimens were picked up. They are of the same material as the ordinary pottery, and have in most cases been painted with rude designs. The finest example is given in this figure. They are usually from two to five inches in diameter and about one-half an inch in thickness.

Sections of two varieties are given in Figure 9. These disks were doubtless used as lids for the various narrow-necked vessels. This specimen fits the vessel given in Figure 7, although not found in the same locality.

W.H.Holmes, del. & lith. T. Sinclair & Son, 1877.

ANCIENT POTTERY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H.H.NICHOLS Sc.
W.H.H.

In Figures 10, 11, and 12 I give three specimens from the collection made by Dr. Palmer in Saint George, Utah; they have no corresponding forms in our collections.

PLATE XLVI.

This plate contains drawings of a number of stone implements, arrowheads, ornaments, and other articles manufactured or used by the ancient inhabitants of this region. Nearly all were found so associated with the architectural remains that I do not hesitate to assign them to the same period.

Figure 1 represents a small fragment of rush matting, a large piece of which was found on the floor of the "sixteen-windowed" cliff-houses of the Rio Mancos. It was probably manufactured from a species of rush, *Scirpus validus*, that grows somewhat plentifully along the Mancos bottoms.

Figure 2 represents a bundle of small sticks, probably used in playing some game. They are nearly a foot in length, and have been sharpened at one end by scraping or grinding. They were found in one of the cliff-houses of the Mancos, buried beneath a pile of rubbish. The bit of cord with which they are tied is made of a flax-like fibre, carefully twisted and wrapped with split feathers; beside this a number of short pieces of rope of different sizes were found, that in beauty and strength would do credit to any people. The fibre is a little coarser and lighter than flax, and was probably obtained from a species of *yucca*, which grows everywhere in the Southwest.

Figure 3 is a very perfect specimen of stone implement found buried in a bin of charred corn in one of the Mancos cliff-houses.

It is 8 inches in length and 2½ inches broad at the broadest part; its greatest thickness is only ½ an inch. One face is slightly convex, while the other is nearly flat. The sides are neatly and uniformly rounded, and the edge is quite sharp. It is made of a very hard, fine-grained, silicious slate, is gray in color, and has been ground into shape and polished in a most masterly manner. Although its use is not positively determined, it belongs, in all probability, to a large class of implements called *celts*. This specimen has probably been used for scraping skins or for other similar purposes, but certainly not for striking or cutting, as the material is very brittle. The most conclusive proof of its use is the appearance of the edge, which shows just such markings as would be produced by rubbing or scraping a tough, sinewy surface.

Figure 4 represents a part of a *metate* or millstone. The complete implement consists of two parts—a large block of stone with a concave surface, upon which the maize is placed, and a carefully-dressed but coarse-grained slab of stone for grinding. This slab is generally from 8 to 12 inches long by 3 to 6 wide, and from 1 to 2 inches thick. The specimen illustrated is made of black cellular basalt, and was found with many others at the ruined pueblo near Ojo Caliente, New Mexico. Fragments of these primitive mills are to be seen at nearly every ruined pueblo that I have examined.

Figure 5, a very much worn specimen of stone axe, which was found at an ancient ruin near Abiquiu, New Mexico. It is made of light-colored chloritic schist, and measures 2 inches in width by 3 in length.

Figures 6 and 6*a* are specimens of ear-ornaments, such as are found in connection with very many of the ruins of Southern Colorado. These are made of fine-grained gray slate, only moderately well polished, and measure an inch and a quarter in length.

Figure 7 represents a marine shell of the genus *Olivella*, obtained

probably from the Pacific coast. Large numbers of this and allied shells are found about these ruins. They are generally pierced, and were doubtless used as beads.

Figure 8 represents a small carved figure found on the Rio Mancos. It is made of hard gray slate. Its use or meaning cannot be determined.

My conclusions in reference to the history of the ancient inhabitants of this region, as drawn from my observations among the ruins, briefly outlined, are as follows:

The ancient peoples of the San Juan country were doubtless the ancestors of the present pueblo tribes of New Mexico and Arizona. A comparison of the ancient with the modern architecture and a consideration of the geographical relations of the ancient and modern pueblos lead very decidedly to this conclusion. They have at one time or other occupied a very extensive area which includes the greater part of the drainage of the Rio Colorado. Their occupation of this region dates back very many centuries, as attested by the extent of the remains and their advanced state of decay.

The final abandonment of the cliff and cave dwellings has occurred at a comparatively recent date, certainly subsequent to the Spanish conquest.

The lowland remains, the extensive pueblos and great towers, are generally in a very much more advanced state of ruin than the cliff defences. It is possible that the latter owe their construction to events that immediately preceded the expulsion of the pueblo tribes from this region.

The cliff-builders were probably not greatly superior to the modern pueblos in any of the arts, and I doubt if they could boast of a state of civilization equally advanced.

It should be remembered that up to this time no excavations whatever have been made among these ruins, and I feel as if more information should be obtained before attempting to draw other than very general conclusions. It seems to me probable that a rich reward awaits the fortunate archæologist who shall be able to thoroughly investigate the historical records that lie buried in the masses of ruins, the unexplored caves, and the still mysterious burial-places of the Southwest.

REPORT OF WILLIAM H. JACKSON.

LETTER OF TRANSMITTAL.

WASHINGTON, D. C., *March* 1, 1878.

SIR: I have the honor herewith to transmit a report on the ancient ruins examined by me in 1875 and 1877.

A preliminary report on the ruins examined in 1875 was published in the Bulletin of the Survey, Vol. II, No. 1. The edition is exhausted, and as it was limited it has been thought advisable to revise the report and republish it with the report for 1877. The illustrations have also been revised and additions made.

Hoping this report may meet with your approval, I am, very respectfully, your obedient servant,

WM. H. JACKSON.

Dr. F. V. HAYDEN,
United States Geologist in charge.

REPORT ON THE ANCIENT RUINS EXAMINED IN 1875 AND 1877

CHAPTER I.

RUINS OF SOUTHWESTERN COLORADO AND ADJACENT TERRITORY.

In continuing the investigation (commenced in 1874) of the very interesting ruins scattered throughout the San Juan Basin, I proceeded to Parrott City, a frontier mining-camp on La Plata River, where I procured the services of Harry Lee as guide and interpreter. Mr. E. A. Barber, naturalist, and special correspondent of the New York Herald, was also of the party. Providing ourselves with the supplies which had been forwarded to this point via Tierra Amarilla, we started out late in July, journeying westwardly to the point on the Hovenweep from which we had turned back last year, and where we resumed our explorations.

GENERAL DESCRIPTION OF THE COUNTRY.

The Hovenweep (*deserted valley*) is a tributary of the McElmo, which, together with the wide-spreading arms of the Montezuma, drains into the San Juan all that portion of the country lying between the Mesa Verde and the Sierra Abajo, covering in the aggregate some 2,500 square miles. Their labyrinthine cañons head close to the Dolores on the north, and ramify the plateaus in every direction with an interminable series of deep, desolate gorges, and wide, barren valleys. There is not a living stream throughout this whole region. During the summer months water occurs in but very few places, generally in pockets, sometimes in springs, where the excess, if any, is soon swallowed up by the hot and thirsty sands. The rainy season is in winter and the early spring months, when the water is more generously distributed, being then found in the many basins scattered over the bare tops of the mesas, as well as in the beds of the cañons, the lower temperature of the colder season preventing the rapid evaporation of summer and autumn weather. As a great proportion of the surface of this region is a bare bed of rock, with a soil in the lowlands nearly impervious to moisture, the winter showers soon gather their waters together in great floods in the main channels, and, rushing down in a solid body, form the deep "washes" so characteristic of the country. But these torrents are short-lived, and it is only by noting the height of the drift-material lodged upon the trunks of the venerable cottonwoods bordering the banks that we can fully realize such great bodies of water ever having existed in so dusty a bed. Every cañon and valley has its corresponding wash, worn perpendicularly down through the dry, easily-eroded soil, forming circuitous but excellent pathways. In some valleys, where the drainage is considerable, these washes frequently attain a depth of from 30 to 40 feet, and are impassable for miles.

The intervening table-lands obtain a very nearly uniform height of 500 feet, running up to over 1,000 feet as we approach the Dolores divide. In the wider valleys the maximum is reached by successive steps or benches, rising one back of the other, while in the narrow cañons the ascent is more abrupt; the upper third of the escarpment being generally perpendicular, with the lower two-thirds composed of talus. Their summits and sides are usually clothed with a growth of scrubby piñon and juniper trees, increasing in density and size as we approach the divide on the north, while the valleys below sustain dense masses of sage-brush and greasewood, that, in some places, attain a height of from 10 to 12 feet. Vigorous, fresh-looking cottonwoods line the main channels, and are as deceptive to the thirsty traveller as a mirage. One may travel for miles in the parched bed of the wash at their feet, while overhead their wide-spreading branches cast a grateful shade, and yet not be able to find a drop of water anywhere in their vicinity.

West of the Montezuma two or three small tributaries of the San Juan head in the southern face of the Sierra Abajo, and then comes Epsom Creek, rising among the plateaus farther to the west—so called from the water in one portion of its beds tasting like Epsom salts and having its characteristic effect on the animal system. For a distance of some 25 miles above its mouth the valley of this creek presents upon its eastern side a remarkable wall, some 400 feet in height, insurmountable throughout its whole length, with the exception of one place, where the Indians have made a way for themselves. It is caused by an immense fold in the sandstones, running north and south in a semicircular line, for some 40 miles, and the valley has been eroded from the portion where the strata stood nearly perpendicular. On the west the beds sweep up in graceful curves to a nearly horizontal position, upon which isolated mesas rise above the general level in bold relief against the sky.

The Rio San Juan drains a great interior basin, covering over 20,000 square miles, as well as several great mountain masses bordering it. The river at the mouth of the McElmo has an average width of 50 yards, and a depth of from 4 to 6 feet; its current moving somewhat sluggishly in great sweeping curves that almost touch upon themselves again. The water is warm, and well freighted with the soil, which it is continually undermining; contrasting strongly with the clear, ice-cold tributaries which give it existence. The bottoms are from 3 to 5 miles in width, and, bordering the stream, covered with dense growths of cottonwoods and willows. The broad and fertile alluvial lands, well covered with grass, and the low sage-brush benches bordering them, will undoubtedly prove a rich agricultural possession at no distant day. Back of all upon either hand rise the precipitous sandstone bluffs, picturesque in outline and color, that gradually close down upon the river until it is engulfed in the great cañon which commences just below the mouth of the Rio De Chelly. It is then lost to all knowledge until it reappears mingling its waters with those of the still more turbid Colorado.

South of the San Juan, the Rio De Chelly, coming in opposite the mouth of Epsom Creek, does not differ in its cañon character from those of the north. The bordering plateau, however, is more massive and less cut up by side cañons. The same aridity prevails throughout nearly its whole length.

Having thus superficially surveyed the region, on which are to be found a vast number of prehistoric ruins, we will now return to the Hovenweep, and examine, in such detail as our rapid reconnoissance will allow, the more prominent of the abundant remains.

RUINS OF THE HOVENWEEP AND M'ELMO.

Starting from the Pueblo of the Hovenweep described on page 30 of Bulletin No. 1, second series, we do not find in the immediate neighborhood any other ruins of importance, but a short distance down the cañon they begin to occur quite frequently. We observe first, on the left, the remains of a tower perched upon a rock, jutting out into the valley, beneath and about which are other ruins, evidently belonging to the tower. In the vicinity "rock-shelters" occur upon either side of the cañon, some merely as walled-up caves, while others are semicircular walls built out from the rock and protected overhead by an overhanging ledge. Some seven miles from the Pueblo, and about three miles above the McElmo, on the western side of the valley, is a jagged, butte-like promontory of brownish-yellow sand-rock, standing out from the mesa, upon the face of which are a number of benches and cave-like recesses. These have been built up and enclosed with neatly-laid walls, making six different houses or sets of rooms upon three benches, one above the other. Access was had from below by ascending a steep slope of *débris* for about 100 feet to the foot of the rock, where we find the first and largest of the houses. This is some 12 feet in length by 5 feet deep, divided midway into two rooms, but rendered somewhat indistinct by the falling down of a portion of the rock back of it. The second bench contained the ruins of a row of three small rock-shelters. Above these were two similar ruins, very difficult to reach, the ledge upon which they stand projecting over the one beneath. The perfectly flat floor of the valley at the foot of the rock contained faint indications of having been occupied by buildings. One of the curves of the wash, here some 10 feet in depth, in cutting away the soil had exposed a thin stratum of charcoal about 6 feet below the surface. One piece that we picked out was 3 inches thick, and the earth about the mass in which it occurred was much burnt, as though the fire had been long continued. About a mile farther down we came to an expansion of the valley with a cañon opening in from the west.

In an examination of this for six miles, we failed to discover any remains of stone buildings, but found very numerous indications of what were probably adobe structures, or earthen foundations for wooden ones; in every instance circular, with a diameter of from 15 to 25 feet. A dozen such were found within three miles of each other. Fragments of pottery of excellent quality and neatly ornamented were very abundant. Opposite the mouth of this cañon the mesa juts prominently into the valley. Half-way up its face is a bench-like spur, upon which rests an almost perfectly rectangular block of sandstone that has fallen from the cliff above. It measurers 38 by 32 feet and is 20 feet high. The upper surface is entirely covered with the remains of a wall from 3 to 5 feet high running around its outer edge; a diagonal line divides its interior into two nearly equal spaces, one of which is again subdivided into three smaller rooms. The passages between the latter are formed by the overlapping of the ends of the dividing walls, their opposite ends being set off from each other about 20 inches, thus necessitating a zigzag course in passing from one to the other. At the foot of the south side of the rock, and directly beneath the subdivided half of it, there is a line of stone wall enclosing a space 40 feet square, the rock forming one side, with the centre depressed a couple of feet below the surrounding level. In the right-hand corner of this enclosure, against the rock, are the ruins of another building 20 feet square. Ten feet above the base, and over this ruin, four holes, 6 inches deep and 4 inches in diameter, have been

drilled into the rock, serving evidently to support the roof of the building below, and to afford a means of access to the rock above, a doorway in the surrounding wall being plainly indicated at that point.

Two miles farther down, the McElmo comes in at right angles from the east, and upon the point of the mesa included in the angle thus formed by the two cañons or valleys—we cannot call them streams—is a group of ruins similar to those already described, but much less regularly built. An interesting inscription covering some 60 square feet of surface occurs upon the under face of a large rock, supporting a ruin; animals resembling goats, lizards, human figures, and many hieroglyphical signs abound. While sketching these, our attention was called by Mr. Holmes (who accompanied us thus far with his division on his way to the San Juan, and who had ascended to the summit for the purpose of sketching) to some very interesting remains that he had discovered on the summit of the mesa. The perpendicular scarp of the mesa ran around very regularly, 50 to 100 feet in height, the talus sloping down at a steep angle. On cave-like benches at the foot of the scarp is a row of rock-shelters, much ruined, in one of which was found a very perfect polished-stone implement. Gaining the top of the mesa with some difficulty, we found a perfectly flat surface, 100 yards in width, by about 200 in length separated from the main plateau by a narrow neck, across which a wall had been thrown, but which is now nearly levelled. Almost the entire space fenced in by this wall was covered by an extended series of small squares, formed by thin slabs of sand-rock set on end. All were uniform in size, measuring about 3 by 5 feet, and arranged in rows, two and three deep, adjusted to various points of the compass. There were also a few circles disposed irregularly about the enclosed area, each about 20 feet in diameter, their circumferences being formed of similar rectangular spaces, leaving a circular space of 10 feet diameter in the centre. These rectangles occur mainly in groups, and are found indiscriminately scattered through the whole region that has come under our observation upon the mesa tops and in the valleys. They all have the same general shape and size, and are seldom accompanied by even the faintest indication of a mound-like character. We have always supposed them to be graves, but have not as yet found any evidence that would prove them such. Some, that we excavated to the depth of 5 and 6 feet in a solid earth that had never been disturbed, did not reward our search with the faintest vestige of human remains. In nearly every case, however, a thin scattered layer of bits of charcoal was found from 6 to 18 inches beneath the surface. In one instance, near the Mesa Verde, the upright slabs of rock which enclosed one of these rectangles were sunk 2 feet into the earth and projected 6 inches above it.

In another was found a mass of charred matter that promised to throw some light upon the subject, but a chemical analysis by Dr. Endlich proved it to be simply charred juniper wood, without perceptible admixture of animal matter. As the soil on the summit of the mesa at the junction of the Hovenweep and McElmo was thin and sandy, in some places blown entirely off, leaving the bare bed-rock exposed, there being only from 12 to 18 inches of earth to remove, we excavated several of these with pick and shovel. In no case did we find anything more than the scattered charcoal spoken of above. In some the earth was calcined, as though a fire had been made within them, while in others there was no vestige of a fire beyond the presence of the charcoal. The question very naturally arises as to whether they might not have been cremationists, a supposition that would have some appearance of likelihood,

could we but find any trace of human remains among the bits of charred wood.

Scattered over the whole surface of this mesa were a great many flint-chippings, from among which we picked up a number of very beautiful arrow-points. As the summit commands a wide sweep of country, it is not unlikely that sentries of old beguiled their tedious watch with arrow-making.

From the camp at the Pueblo, Mr. Chittenden, of Mr. Holmes's division, rode up the Hovenweep some eight miles, to where it divided into two equal branches, and upon the point between these forks he found the remains of a round tower, commanding an extended view down the main cañon. No other ruins were noticed.

The parties, under the guidance of Mr. Gardner, camped one night near the head of the Hovenweep, and found there an important group of ruins, described as follows by Mr. Adams:

"The first of these we met are situated at the upper edge of the side of the cañon, about one-third of the distance from the top, on a ledge about 300 feet long and 50 wide. On this small space were crowded some 40 houses, as well as we could judge from the ruins. The general plan of structure was circular, varying in size, but generally from 10 to 15 feet in diameter. The stone was dressed to three times the size of an ordinary brick and in the same shape. * * * The whole arrangement of the little town was for defense; perched up high above, on the summits of bowlders, were little watch-towers, which commanded the plateau above."

Between the Montezuma and the Hovenweep is a high plateau, running north and south from the San Juan to the Dolores; the southern portion is a level sage-covered plain, while the northern is undulating and covered with junipers and piñon pine. Upon this we found the remains of many circular towers, generally occupying slight eminences, and, with but one or two exceptions, as far as we observed, they were so demolished that not one stone remained upon another. In one of these exceptions, about half the circumference of a tower remained, 15 feet in height and of average masonry. Broken pottery was but sparingly scattered about, showing them not to have been occupied as much as the very similar remains in the valleys below. This mesa, averaging 500 feet in height above the surrounding country, does not contain a spring or drop of water, except such as may remain in the holes in the rocks after a shower. The soil is thin and sandy, blown off clean to the bed-rock in places, yet what there is is well grassed, and sage-brush flourishes luxuriantly. As cultivation was out of the question, and permanent residence improbable, it is very likely these towers were lookouts or places of refuge for the shepherds, who brought their sheep or goats up here to graze, just as the Navajos used to, and as the Utes do at the present time. Rude huts of a later day are now found scattered over its surface by the side of the washes, where water would be likely to collect after showers.

RUINS OF THE RIO SAN JUAN.

In travelling down the San Juan, from the mouth of the McElmo, there are not within the first 10 or 12 miles any ruins that would claim attention during a rapid reconnoissance. Indistinguishable mounds of earth frequently occur along the bottom-lands, surrounded by the ever-present fragments of pottery, showing them to be the sites or the remains of

habitations; the quantity of pottery, domestic utensils, and arrow-points helping somewhat to determine the length of time they were occupied.

Crossing the mouth of the broad sandy wash of the Montezuma, which is here bordered with groves of brilliantly-green cottonwoods along its arid course, we pass about three miles below, and find camp under a grove of patriarchal trees within a well-grassed bend of the river. A wide gravelly bench, some 50 feet in height, and running back to the bluff line, rises abruptly from the bottom-lands. A few rods below camp, the river in its meandering sweeps close to the foot of this bench, producing an almost perpendicular face. Upon the top of the bench at this point, overlooking the river, are the ruins of a quadrangular structure of peculiar design.

Referring to the ground-plan, as shown in Fig. 2, Plate XLVIII, we see that it is arranged very nearly at right angles to the river: its greatest depth is on the left, where it runs back 120 feet, the front sweeping back in a diagonal line, so that the right-hand side is only 32 feet in depth. The back wall is 158 feet long, and at right angles to the two sides. In the centre of the building, looking out upon the river, is an open space 75 feet in width and averaging 40 feet in depth, its depressed centre being divided nearly equally by a ridge running through it at right angles to the river. We judged this to have been an open court, because there was not the least vestige of a wall in front or on the ridge through the centre, while upon the other three sides the walls were perfectly distinct; although it is difficult to explain why it should have been hollowed out in the manner shown in the plan, unless the depressions mark the former sites of underground apartments. Back of this court is a series of seven apartments of equal size, springing in a perfect arch from the heavy wall facing the court, leaving a semicircular space in the centre 45 feet across in its greatest diameter. Each apartment is 15 feet in length and the same number of feet in average width across the centre; the walls are somewhat irregular in thickness, but average 20 inches, being compact and well laid. On the left are three rooms extending across the whole width of the building, each averaging 45 by 40 feet; on the right only one was discernible. Our impression was that back of the circle the walls diverged in the manner shown in the plan, although there is so much confusion resulting from the heaping up of the *debris* that much must be left to conjecture. There is also some doubt in regard to the wall facing the river on the right; it is barely possible that it extended somewhat farther out, and that it has become entirely obliterated by its foundations giving way. The remains of the wall above, however, and the fact that there is here a steep inclination to the brink of the bluff, led us to believe that it had been originally built in the way it is shown in the plan. Extreme massiveness is indicated throughout the whole structure, both by the amount of *debris* about the line of the walls, forming long, rounded mounds, 4 to 5 feet high, and by the stone-work cropping out, 20 to 24 inches in thickness. Portions of the outer wall have fallen outward almost in solid pieces, the stones remaining spread out in much the same order they occupied in the standing wall. The stones are of fair size, but yet not so large but that one man can handle the largest of them. They were obtained from the neighboring bluff, and probably undressed, but broken into very nearly rectangular blocks, so that when carefully laid and dressed up with adobe cement they would all have the effect of dressed stone. Their extreme age, which has crumbled a great many into dust and rounded the asperities of all into shapeless bowlders, renders any conjecture upon this point somewhat uncertain. Where portions of the undisturbed wall appear above the rubbish, it

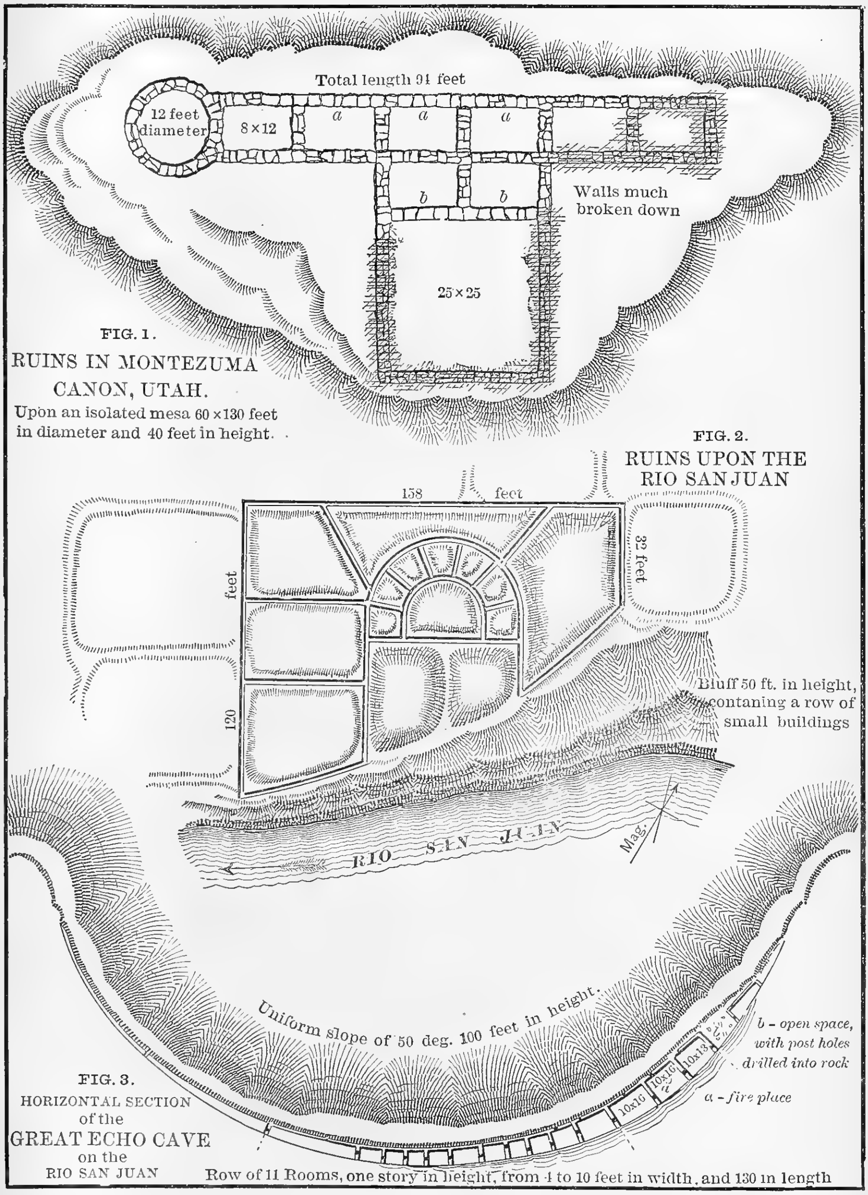


FIG. 1.
RUINS IN MONTEZUMA CANON, UTAH.
Upon an isolated mesa 60×130 feet in diameter and 40 feet in height.

FIG. 2.
RUINS UPON THE RIO SAN JUAN

FIG. 3.
HORIZONTAL SECTION of the GREAT ECHO CAVE on the RIO SAN JUAN

shows a solid, well-constructed masonry. No indications whatever could be found of any passage-ways, nor could we expect to find any so near their base, for all the apartments were probably entered by ladders, the same as in other buildings of this order that we have found in other localities.

Upon either side and back of this building were low, indefinite lines of earth, not more than 12 to 18 inches above the surrounding surface, enclosing areas from 40 to 60 feet in diameter, which were probably corrals for domesticated animals; the walls being composed of adobe or turf brought from the valley below, would, of course, wash down to a barely perceptible ridge.

In the face of the bluff immediately under this ruin, and upon a recessed bench situated about half-way between top and bottom, is a row of little "rock shelters." A strata of a rotten shaly sandstone has been weathered or dug out, probably both, for a distance of 300 feet along the bluff, to a depth of about six feet, leaving a firm floor, and a projecting ledge overhead, with just room enough to walk along without stooping. A continuous row of buildings occupied this bench, although most of them have tumbled into the river, and none have their front walls remaining. Door-ways through each of the dividing walls afforded access along the whole line. A few rods up stream, and in the same line of the bluff as the preceding, was another little niched cave-house, 14 feet in length, 5 feet high at the centre and 6 deep, divided into two equal apartments; a small square window, just large enough for one to crawl through, was placed midway in the wall of each half. We well might ask whether these little "cubby-holes" had ever been used as residences, or whether, as seems at first most likely, they might not have been "caches," or merely temporary places of refuge. While, no doubt, many of them were such, yet in the majority the evidences of use and the presence of long-continued fires, indicated by their smoke-blackened interiors, prove them to have been quite constantly occupied. Among all dwellers in mud-plastered houses it is the practice to freshen up their habitations by repeated applications of clay, moistened to the proper consistency, and spread with the hands, the thickness of the coating depending upon its consistency. Every such application makes a building appear perfectly new, and many of the best sheltered cave-houses have just this appearance, as though they were but just vacated.

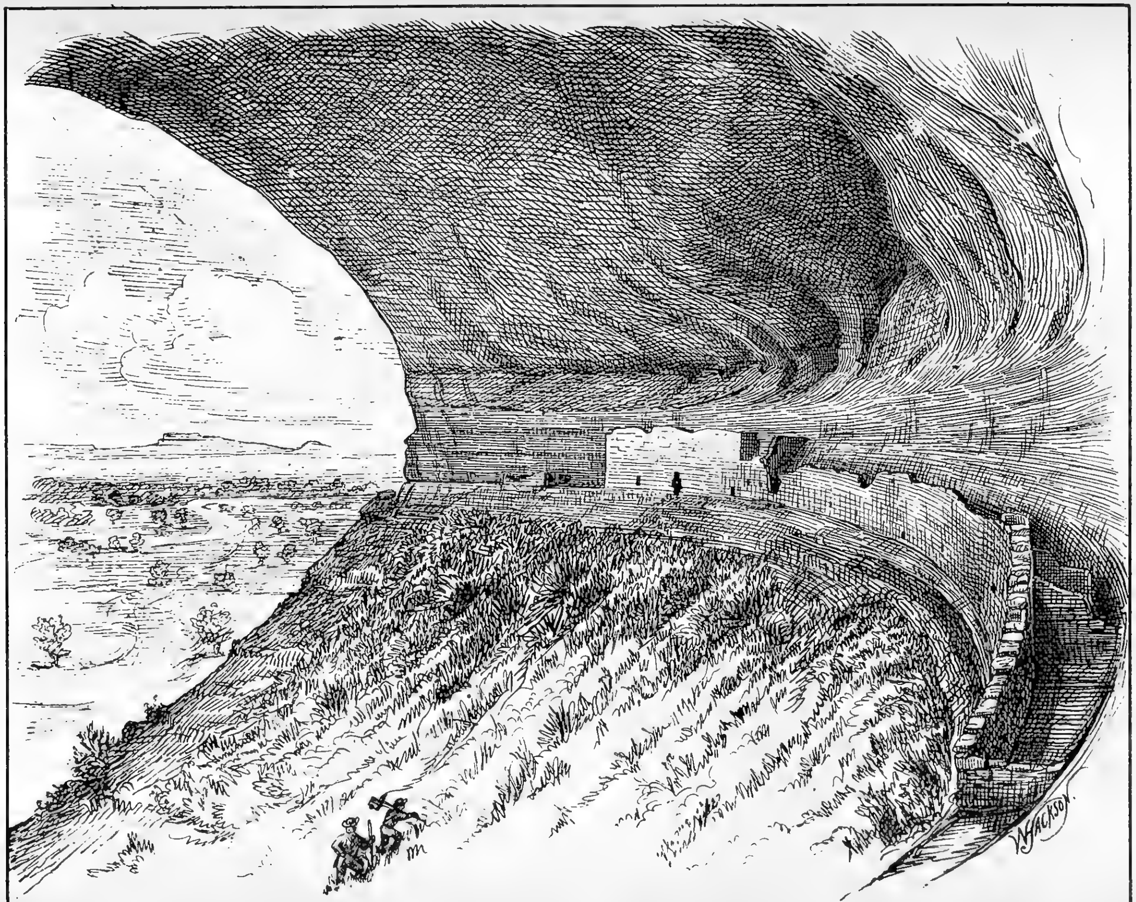
A quarter of a mile back from the river, rising from the level bench, is a long narrow hill about 100 feet in height, commanding an extended view up and down the valley, upon the summit of which is one of the circular, mound-like enclosures which occur so frequently on both the highlands and the lowlands. It evidently has some connection with the group below on the river's edge, for there are no other ruins within several miles.

Continuing down the river, under the great bluffs which border it closely, we find many ruins of the "rock-shelter" kind occurring frequently in all sorts of positions, from the level of the valley to a height of over 100 feet, and from the smallest kind of a "cache," not larger than a bushel-basket, to buildings that probably sheltered several families. One group consists of a row of three small houses built upon a ledge running horizontally along the perpendicular face of the bluff, about 60 feet above the trail immediately below it. The ledge was so narrow that the buildings occupied every available inch of its surface. As near as we could judge from below, each was about 5 feet wide and 10 long, with apertures through their end walls, and windows in the outer

wall of the first two. No possible means of access were discernible, and if ladders were ever used they were taller than any of the trees available for that purpose now growing in this vicinity.

About twelve miles below the Montezuma we discovered, far away upon the opposite side of the river, a great circular cave, occupying very nearly the entire height of the bluff in which it occurred, and in which, by close inspection with the glass, we were enabled to make out a long line of masonry. Fording the river and approaching it, we found that the bluff-line at this place was a little over 200 feet in height, the upper half a light-colored, firm, massive sandstone, and the lower a dark-red and shaly variety. The opening of the cave is almost perfectly circular, 200 feet in diameter, divided equally between the two kinds of rocks, reaching, within a few feet, the top of the bluff above and the level of the valley below. It runs back in a semicircular sweep to a depth of 100 feet; the top is a perfect half-dome, and the lower half only less so from the accumulation of *débris* and the thick brushy foliage, the cool dampness of its shadowed interior, where the sun never touches, favoring a luxuriant growth. A stratum of harder rock across the central line of the cave has left a bench running around its entire half-circle, upon which is built the row of buildings which caught our attention half a mile away. Figure 3, Plate XLVIII, is a plan of a horizontal section of the cave, showing the ledge and the manner of the disposition of the buildings upon it, and in Plate XLIX, the ruins as they now appear.

The houses occupy the left hand or eastern half of the cave, for the reason, probably, that the ledge was wider on that side, and the wall back of it receded in such a manner as to give considerable additional room for the second floor, or for the upper part of the one-story rooms. It is about 50 feet from the outer edge of the cave to the first building, a small structure 16 feet long, 3 feet wide at the outer end, and 4 at the opposite end; the walls, standing only 4 feet on the highest remaining corner, were nearly all tumbled in. Then came an open space 11 feet wide and 9 deep, that served probably as a sort of workshop. Four holes were drilled into the smooth rock floor, about 6 feet equidistantly apart, each from 6 to 10 inches deep and 5 in diameter, as perfectly round as though drilled by machinery. We can reasonably assume that these people were familiar with the art of weaving, and that it was here they worked at the loom, the drilled holes supporting its posts. At *b*, in this open space, are a number of grooves worn into the rock in various places, caused by the artificers of the little town in shaping and polishing their stone implements. The main building comes next, occupying the widest portion of the ledge, which gives an average width of 10 feet inside; it is 48 feet long outside, and 12 high, divided inside into three rooms, the first two 13½ feet each in length, and the third 16 feet, divided into two stories, the lower and upper 5 feet in height. The joist-holes did not penetrate through the walls, being inserted about six inches, half the thickness. The beams rested upon the sloping back wall, which receded far enough to make the upper rooms about square. Window-like apertures afforded communication between each room all through the second story, excepting that which opened out to the back of the cave. There was also one window in each lower room, about 12 inches square, looking out toward the open country, and in the upper rooms several small apertures, not more than 3 inches wide, were pierced through the wall, hardly more than peep-holes. The walls of the large building continued back in an unbroken line 130 feet farther, with an average height of 8 feet. The space was divided into 11 apartments,



AM. PHOTO-LITHO. CO N.Y. (OSBORNE'S PROCESS.)

with communicating apertures between them. The first room was 9½ feet wide, the others dwindling gradually to only 4 feet in width at the other extremity. The rooms were of unequal length, the following being their inside measurements, commencing from the outer end, viz: 12½, 9½, 8, 7½, 9, 10, 8, 7, 7, 8, 31 feet; the ledge then runs along 50 feet farther, gradually narrowing, where another wall occurs crossing it, after which it soon merges into the smooth wall of the cave. The first of these rooms had an aperture large enough to crawl through, leading outward; the wall around it had been broken away so that its exact size could not be determined; all the others, of which there were about two to each room, were mere peep-holes, about 3 inches in diameter, and generelly pierced through the wall at a downward angle. No sign of either roofing or flooring material could be found in any of the rooms. Everything of that kind has been thoroughly burned out or removed, so that not a vestige of wood-work remains. We cannot be positively certain that they had ever been roofed, the mild temperature of this region hardly necessitating any other covering than such as the ample dome of the cave itself offered. In the central room of the main building we found a circular basin-like depression (*a*), 30 inches across and 10 deep, that had served as a fireplace, being still filled with the ashes and cinders of aboriginal fires, the surrounding walls being blackened with smoke and soot. This room was undoubtedly the kitchen of the house. Some of the smaller rooms appear to have been used for the same purpose, the fires having been made in the corner against the back wall, the smoke escaping overhead. The masonry displayed in the construction of the walls is very creditable; a symmetrical curve is presever throughout the whole line, and every portion perfectly plumb; the subdivisions are at right angles to the front. The stones employed are of the size used in all similar structures, and are roughly broken to a uniform size. More attention seems to have been paid to securing a smooth appearance upon the exterior than the interior surfaces, the clay cement being spread to a perfectly plane surface, something like a modern stucco finish. In many places, of course, this had peeled away, leaving the rough, ragged edges of the stones exposed. On the inner walls of some of the subdivisions that appear to have been less used than others, the impressions of the hands, and even the delicate lines on the thumbs and fingers of the builders, were plainly retained; in one or two cases a perfect mould of the whole inner surface of the hand was imprinted in the plastic cement. They were considerably smaller than our own hands, and were probably those of women or children. In the mortar between the stones several corn-cobs were found embedded, and in other places the whole ear of corn had been pressed into the clay, leaving its impression; the ears were quite small, none more than 5 inches long. In the rubbish of the large house some small stone implements, rough indented pottery in fragments, and a few arrow-points were found. It is a wonder that anything is found, for it is more than likely that every house has been ransacked time after time by wandering bands of Utes and Navajos, who would search with keen eyes for any articles of use or ornament left after the first spoliation. The whole appearance of the place and its surroundings indicates that the family or little community who inhabited it were in good circumstances and the lords of the surrounding country. Looking out from one of their houses, with a great dome of solid rock overhead, that echoed and re-echoed every word uttered with marvellous distinctness, and below them a steep descent of 100 feet to the broad fertile valley of the Rio San Juan, covered with waving fields of maize and scattered groves of majestic cottonwoods, these old people, whom even the imagin-

ation can hardly clothe with reality, must have felt a sense of security that even the incursions of their barbarian fees could hardly have disturbed.

Soon after leaving the Casa del Éco, as we named the last ruins, our trail bore away to the right upon the plateaus, which now began to encroach too closely upon the river to permit us to follow its course, and we came to a second line of bluffs which were gradually also surmounted. The evidences of former occupation continue as numerous as ever, finding shape principally in cave-houses, all too near alike to be described without repetition. A novel feature at one point is a smooth bluff of cream-colored sandstone about 150 feet high, with hardly a seam on its surface, over which has been cut a series of steps. Upon the pile of *débris* at the left are the ruins of some structure that had been built just beneath the line of foot-steps, and was evidently placed there as an approach to them, as they only came down to within about 12 feet of the bottom. A large slab of rock lying against the bluff on the right was separated from it about 3 feet at the base, making a long, narrow passage-way, that could also be reached through a small opening between the rocks on the right; from within this place it was not difficult to reach a round bowlder lodged above, from which starts another line of steps. The surface of the rock has been worn away to such an extent as to nearly obliterate some of the holes, rendering ascent, at the present time, impossible; and as the bluff was inaccessible for two or three miles upon either side, we did not reach the top nor see from below any evidences of building.

Our trail over the bare plateau finally brought us down to the San Juan again just at its junction with Epsom Creek and but a short distance above the mouth of the Rio De Chelly, where we found a pleasant park-like valley, about a mile in length, bordered by groves of cottonwood and willows. The beds of Epsom Creek and the Rio De Chelly were both perfectly dry, like all the tributaries of the San Juan west of the Mancos, although in the latter were indications of occasional flooding, some of the deeper pockets retaining shallow pools of a very red muddy water. Upon every side—except where the broad valley of Epsom Creek opened northwardly, with the deep blue summits of the Sierra Abajo appearing in the vista—steep rugged bluffs of bare red rock are seen, weathering occasionally into sharp needle-like pinnacles, discernible for long distances in every direction. The San Juan emerges from a considerable cañon at the head of this little valley only to sink into a still greater one below. The low stage of water encourages us to explore this lower cañon for a short distance, which we could readily do upon our riding-animals, the indefatigable little Mexico, our pack-mule, carrying the photographic instruments. We penetrated its exceedingly tortuous course about 10 miles, meeting no serious obstruction, and it is likely could have gone much farther. The walls rise abruptly, generally perpendicularly, upon either side, from 1,000 to 2,000 feet in height, but always with a bench covered with a rough talus at the bottom bordering the stream. Former floods and the drifting sands from the plateau above have filled up the interstices in the rocky mass, smoothing the way over them very considerably.

RUINS OF THE RIO DE CHELLY.

In the walls of the cañon of the Chelly, where it opens into the park, are several great circular caves, averaging 100 feet in diameter, in which are the remains of walls and houses, but all very much dilapi-

dated. Upon a ledge on the opposite side of the cañon is a row of four houses, not easily reached, one of which still retained a roof; and in another case, a shelter was formed by inclining a row of sticks across the opening of the cave, with the outside thickly plastered with clay. It had every appearance of being a more recent structure, yet it was in the midst of much older-looking ones, and in an almost, if not quite, inaccessible position.

Over the level surface of the valley the older form of ruins, indicated principally by broken pottery, occurred in several places, and also, on a bench bordering the San Juan, just above Epsom Creek, are a number of small squares arranged in circles, that we have heretofore assumed to be places of sepulture.

In going southward, up the Chelly, we find it necessary to avoid the cañons and make a detour to the right, crossing a rugged depression in the line of bluffs, to the valley of a small tributary, then over another divide across the upturned edges of the great fold spoken of in the first part of this article, to quite an expansion of the valley of the Chelly, about one mile square, covered with sage-brush and drifted sand, on the upper or right-hand side of which we were fortunate enough to find two springs of cool, fresh water, a most delicious luxury where the temperature of the water of the San Juan, the coldest to be had, was 80 degrees, and the temperature of the atmosphere away up in the hundreds during the day-time.

The surface of this valley, or small plain, contains indications of old ruins, about which we picked up many arrows, knives, and other stone implements, with the ever-present pottery. The wash of the Chelly skirts one side of the valley, with perpendicular bluffs 200 to 400 feet high, closely bordering its other bank. Above and below, the opposite bluffs rise again, throwing the wash into deep cañons. An examination of the exceedingly tortuous course of the wash and its accompanying bluff-line for a distance of 5 miles up and down revealed but one ruin (Plate L), a very important and interesting one, however.

This cave-town occurs in a great bend of the encircling line of bluffs, where the wash makes a wide detour, and is perched upon a recessed bench about 70 feet above the valley. It is overhung by a solid wall of massive sandstone extending up over 200 feet higher. The left-hand side of the bench supporting the buildings, sweeps back in a sharp curve about 80 feet under the bluff, and then gradually comes to the front again until, on the extreme right hand, the buildings are built upon a mass of *débris*, but partially protected overhead. The total length over the solidly-built portion of the town is 545 feet, with in no place a greater width than 40 feet. There are somewhere in the neighborhood of 75 rooms upon the ground-plan, with some uncertainty existing as to many of the subdivisions on the right hand in the vicinity of *d* and *e*; but in the cave-built portion every apartment was distinctly marked. Midway in the town is a circular room of heavily and solidly built masonry, that was probably intended for an *estufa* or council hall; that is, if we can reasonably assume any similarity in the methods of building or worship to those of the Pueblos of New Mexico. Starting from this *estufa* is a narrow passage running back of the line of houses on the left to the two-story group, *a*, where it ends abruptly, further access being had through the back row of rooms, or over the roofs of the lower front row, probably the latter, for it is likely that these roofs served as a platform from which to enter the rooms back of it. At the extreme left-hand end a still higher ledge occurs, with the overhanging wall coming down close to it, its outer edge enclosed by a

wall, with a little store-room in its farther corner. This space was reserved, probably, as an out-door working-room. All the buildings of this half are of one story, with the exception of the group *a*, the residence probably of the chief or of some other important family in the community. The rooms just back of it are the store-rooms of the family, where the corn and squashes were put away for the winter's consumption. At the place marked *b*, near these store-rooms, there are two half-round inclosures of stone-work, that are very likely the remains of small reservoirs or springs. The rock back of them is dug out beneath, and had, even in the dry season, when we were there, a damp appearance, as though water was not far removed, and might easily be coaxed to the surface. The front line of wall of this left side of the town is built upon a steep angle of smooth rock, with the interior of the apartments filled up with earth so as to make their floors level, bringing them a little below the passage-way. In two or three instances, as shown in the plan, the front wall has given way, precipitating all but the back wall to the bottom of the cliffs. Holes have been drilled into the rock in a few places beneath the walls, evidently to assist in retaining them in their places.

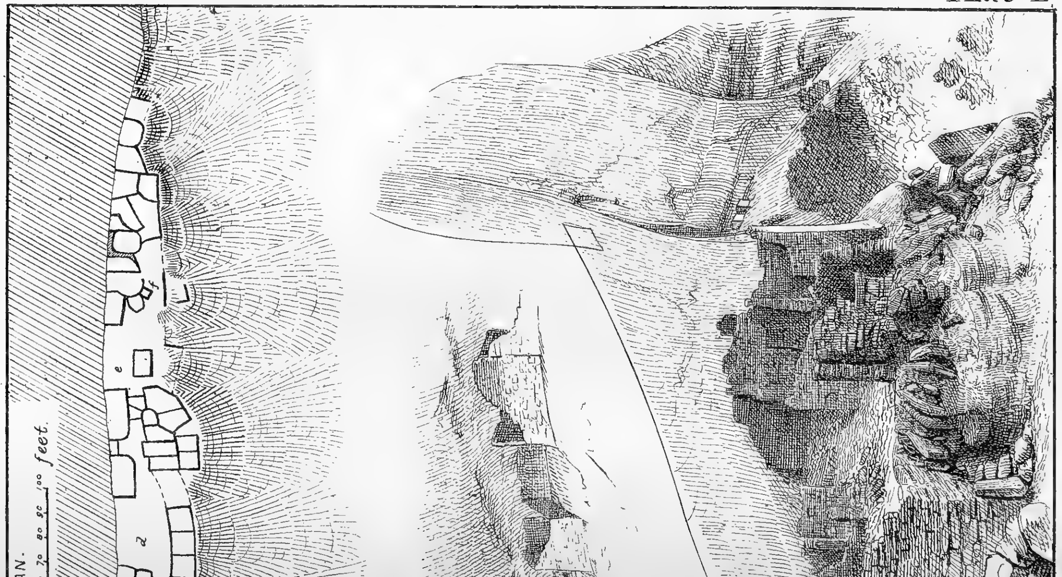
The whole front of this portion of the town is without an aperture, save very small windows, and is perfectly inaccessible, both from the solidity of the wall and the precipitous nature of the foundation-rock beneath it. Admittance was probably gained from near the circular building in the centre, by ladders or any other well-guarded approach over the rocks.

Going to the right from the *estufa* we have to climb up about 8 feet, reaching a narrow ledge that starts out from the bluff. From here to the farther end the buildings are built irregularly over the uneven surface of rocky *débris*, each house conforming to the irregularities by which it is surrounded, but all, as at *d* and *e*, presenting the general arrangement of clusters about central courts, that served, in all probability, as corrals for their domestic animals. In some places near these corrals the under surface has broken away, disclosing a solidly-packed bed of old manure, very nearly resolved into dust, and through which were scattered twigs of willow, fragments of pottery, and sticks of cedar. Some of the rooms are quite large, from 15 to 25 feet in length. The very small rooms surrounding them were probably for storage, and in some cases seem to have answered the purpose of fire-places, as at *f*, for baking pottery, very likely. None of these buildings, as far as we could discover, were of more than one story in height. All the door-ways or windows opened from within the courts or corrals, and were unusually large, reaching in some cases the whole height of the wall. The front line was so broken down that it was impossible to tell to what extent it was accessible, although we may reasonably infer that, with the exception, perhaps, of a way for themselves and their animals, it was not readily so. The bluff itself was easy to ascend, being composed of large rocks, the spaces between being filled with smaller *débris*.

In their construction these buildings differ from any we have yet met, in the thickness, or rather thinness, of their walls, being very seldom more than a foot, or more frequently between that and six inches thick. The stones of which they are built are in long, thin slabs, roughly trimmed down to the required size, and laid in an abundance of adobe mortar. In most of the rooms, both the inside and outside have been smoothly plastered with clay, and, where protected overhead, still retain that coating in fair preservation.

A few rods to the right is another smaller recessed bench, upon which

U.S. Geological Survey. Plate L



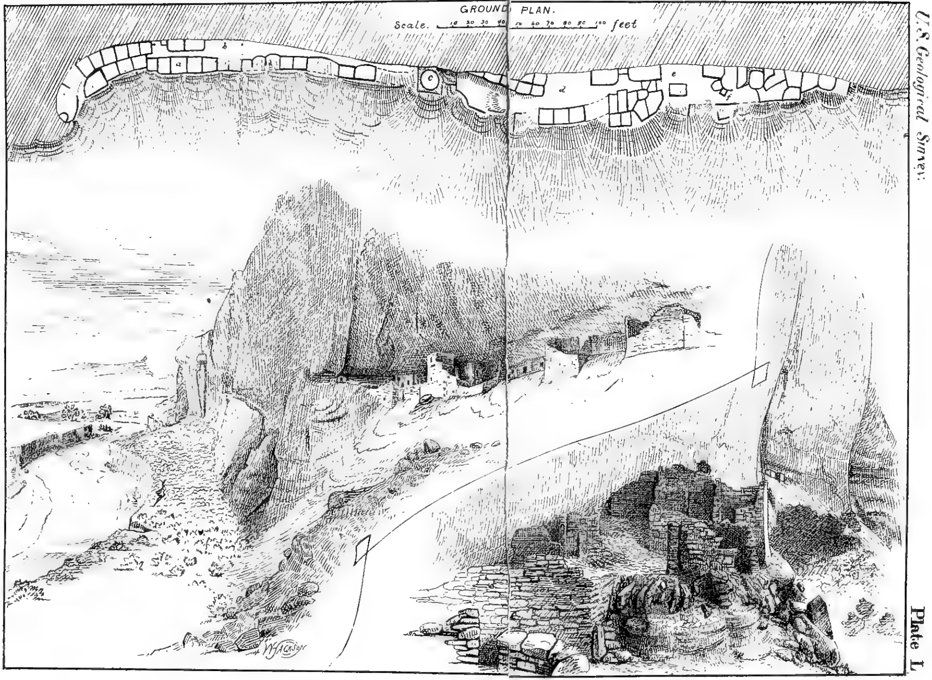


Plate L.

AM PHOTO LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

are built two small houses, each about ten feet square, and one with its roof still entire. The approach from below is a smooth, rocky surface, so steep as to be almost impossible of ascent, and with no remains of any other easier method of getting up.

At the foot of the bluff beneath that portion of the ruin marked *d*, in the ground-plan, a low bench rises about ten feet above the surrounding valley, upon which are indications of old buildings and of other remains—our so-called burial-places. Chipped flint-work was plentiful, as we found a number of very beautiful specimens of arrow-points, perforators, knives, and other domestic utensils. In a mass of *débris* at the foot of the two-story tower, seven large earthen pots of rough indented ware were found imbedded in the soil and filled with earth. They were too fragile to admit of transportation upon pack-animals, so we put them carefully by for future investigators. In the rubbish at the extreme right, a handsome little jug or vase (see Fig. 5, Plate LXV) was found, lacking only its handle. A careful search through the very thick deposits of *débris* would undoubtedly reveal many treasures, and we felt many regrets that we could not consistently devote a number of days to the pleasant undertaking. We can only expect to skim the surface, leaving to others hereafter the more satisfactory duty of exhausting each subject in detail.

In progressing southward we again find it necessary to climb the steep bluffs bordering the Chelly, here so tortuous and walled up as to be impracticable, if not impassable. Once on top, however, we made our way with comparative ease over great dunes of a very fine, yellowish-white sand, packed so solidly as to inconvenience the animals but very little. Much the greater part of the way is over a solid floor of bare, nearly white, sandstone, rising into occasional dome-shaped hillocks, and furrowed by shallow ravines. Sage-brush, juniper, and piñon trees are scattered plentifully over the whole region, affording the only relief to an otherwise perfectly barren desert. Travelling thus over this trackless waste, we reach in about fifteen or twenty miles the bare red plains of the famous so-called diamond-fields of Arizona. Beautiful garnets were found scattered plentifully over the whole region, but they could not tempt us to linger, for the sun beat down upon its arid surface with such an intensity that but for the extreme dryness and salubrity of the atmosphere it would have prostrated anything but a salamander.

After crossing this plain we came suddenly upon a side cañon running across our course, seemingly a mere gash in the rocky plateau, into which we were fortunate enough to find a practicable way for ourselves and animals. But what a contrast! A smooth sward of grass, and thick patches of the tall reedy kind peculiar to damp localities, made a change grateful to both man and beast. Continuing down this cañon—which has, in consequence of its inviting appearance, been called the Cañon Bonito Chiquito—a couple of miles brings us the wash of the Chelly again, bordered with groves of fine old cottonwoods, but its bed, in which were pools of clear water, was so deep as to be almost inaccessible. A band of wandering Navajos just before us, with large flocks of sheep, had, however, made a way down that we found practicable.

An after-investigation revealed the presence of water in large artificial reservoirs, or tanks, in the cañon Bonito, just above where we entered it first, about which are grouped a number of old ruins. This has been a favorite Indian wintering-ground, so that the ruins here have been much modified by their occupation.

Two miles down the cañon of the Chelly we found the house shown in Plate XLVII. Its situation is very similar to that of the town shown in Plate 19, but it is overhung by a less height of the impending bluff. It was reached from the valley by a series of steps cut into the rock, but now so eroded away as to be impracticable. It is accessible now by way of the ledge, some 10 or 12 rods in length, which extends to the left from the house, but affords a very narrow and precarious footing. At the time of occupancy this was walled across, with possibly a way for getting over or around, for this ledge communicated directly with the plateau above, where there are the remains of what was possibly a corral.

The house, 20 feet in height, consists of two stories, built against the sloping back wall of the bluff; the lower story is 18 by 10 feet square, divided into two rooms, one slightly smaller than the other, with a communicating door between, and a large door opening outward from the larger one. The upper floor appears to have been all in one room, with one large window facing outward, and several smaller ones in the side walls. Extensions existed upon either side, and also some kind of structure in front, probably a sort of platform-house, covering the lower doorway. To the right the ledge grows narrower, and gradually merges into the perpendicular bluff; 40 feet from the house, on this ledge, are the remains of a wall across it. About 20 rods above, at the foot of the bluff, there is a deep natural reservoir of water, formed by the accumulated rains upon the plateau above pouring over the rocks and scooping out a basin 30 feet in diameter and fully as deep, that seems to retain a perpetual supply of water.

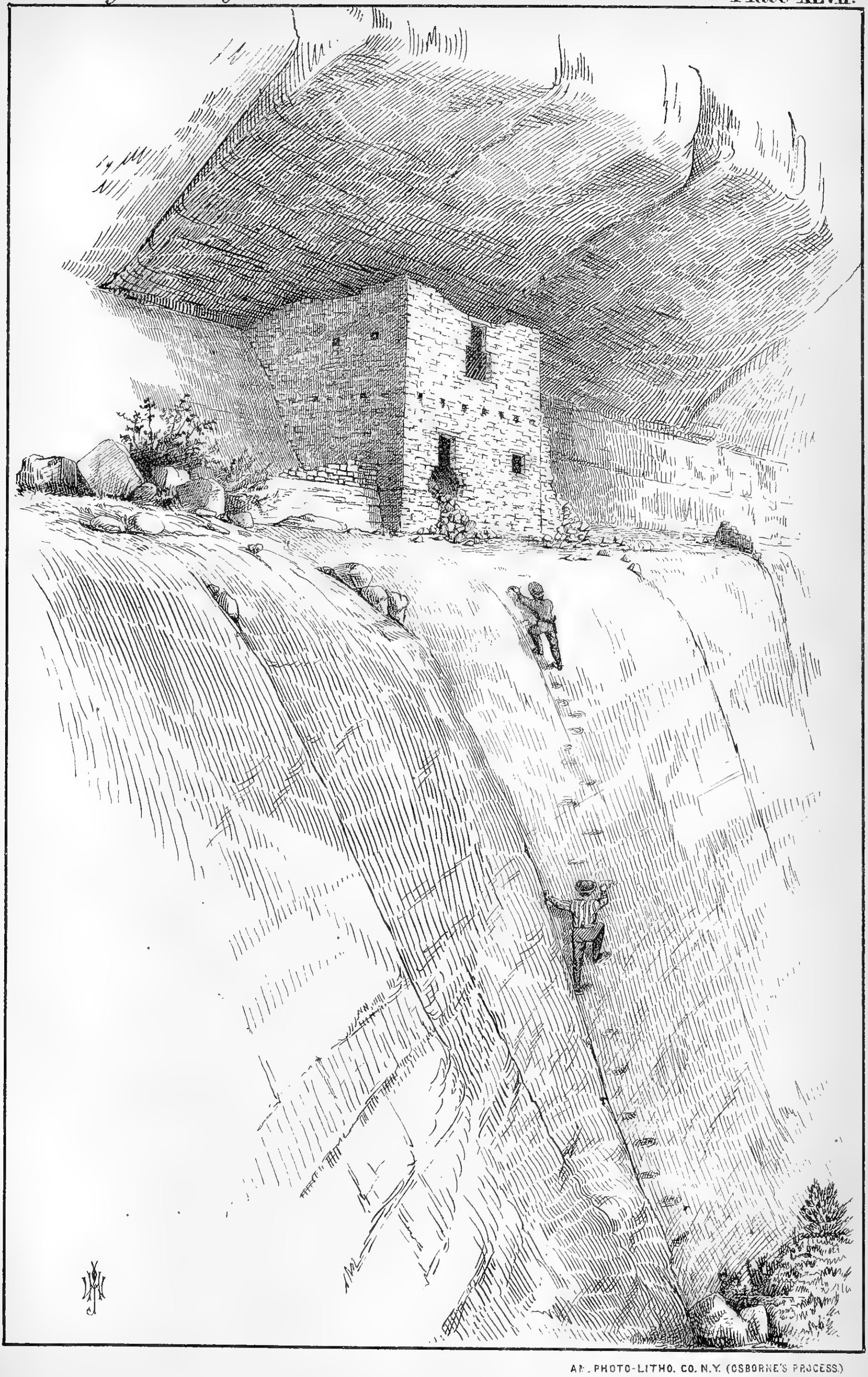
Near our camp, just at the junction of the two cañons, and on the flat surface of the sage-covered valley, is a row of small squares marked out by large stones, such as have already been described, standing on end. In this case the squares were of such careful construction and size as to encourage us to dig into them to a considerable depth. Beyond the scattered bits of charcoal, very sparingly deposited in this instance, however, nothing was found.

Five miles above the cañon Bonito, the Chelly expands into a wide valley that extends, with only slight interruptions, to the foot of the cañon De Chelly, at the northern end of the Tunecha Mountains. It is bordered by low but abrupt sandstone bluffs, which have been broken into isolated monuments in some places, that stand like huge sentinels upon either hand, as if to warn the traveller from the desolation surrounding him. Although the bluffs contain numerous great circular caves, favorite building-places of the ancient builders, we find only two or three ruins of that kind, and these only in the lower end of the valley, the last we noticed being about eight miles above the cañon Bonito. This was the largest and most important one in this vicinity, occupying a large circular cave very similar to the one of the San Juan, divided into twelve or fifteen rooms, with a large corral or court, and an elevated bench on one side, with a low wall running around its front edge. This had been occupied by the Navajos for corraling their sheep.

Over the broad, flat, valley, sage-covered, sandy, and monotonous, and through which the wide shallow wash meandered from side to side, we found frequent indications of its former occupancy by the old people whom we have been following up. These indications extend southward until they are lost in the cultivated region about the head of the valley.

There were no more remains of stone-built houses, nor the slightest sign of one; all were probably of adobe, the only clew in many cases being simply a slight mound with considerable quantities of broken pottery

Plate XLVII.



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

surrounding it. Eight miles up the cañon De Chelly are the ruins of a cave-town very much like the one described (Plate L), but much smaller, and with a ruined mass of houses at the foot of the bluffs below the cave-like bench.* About the head of the valley the Navajo Indians, taking advantage of the water which comes down thus far from the mountains to the east, have under cultivation several hundred acres, planted with corn, pumpkins, and melons. From here our trail to the Moqui settlements branched off in a southwesterly direction to a low divide under the southern end of the Mesa Vaca, where it turned nearly south and hardly deviated from a bee-line for a distance of nearly 40 miles to Tegua, the nearest of the Moqui towns.

We will not now stop to discuss the question as to what connection may have existed between the ancient builders of the San Juan and the present semi-civilized people known as the Moquis, but return to the mouth of Epsom Creek and describe the many curious remains found north of the San Juan, all of which bear some relationship to those of the Hovenweep already noticed.

RUINS OF EPSOM CREEK.

Fifteen miles up Epsom Creek a side cañon comes in from the left, down which trickles a scanty stream of brackish water with the peculiarity of taste and action which has given the name to the whole valley. Camping here, we extended our observations up this lateral cañon some 8 or 10 miles in quest of ruins, and found them numerous enough to satisfy our most earnest desire, although not of the importance of the greater ones of the San Juan and De Chelly. All were of the small cave kind, mostly mere "cubby-holes," but so smoke-blackened inside and showing other marks of use as to convince us they had long been occupied but not during any very recent period. In the generality of cases they were on small benches or in shallow caves situated near the bed of the stream, but the farther up stream we went the higher they were built in the bluffs. In one instance a bluff several hundred feet in height contains half a dozen small houses sandwiched in its various strata, the highest being 150 feet above the valley. Each consists of but one room, and one of them is a perfect specimen of adobe-plastered masonry, hardly a crack appearing upon its smoothly-stuccoed surface. A short distance above the entrance to the cañon a square tower has been built upon a commanding point of the mesa (Plate LI), and in a position perfectly inaccessible so far as any means at our command were concerned. The stones of which it is composed are of a very nearly uniform size, more so than in any of the buildings we have seen west of the Hovenweep.

Upon the opposite side of the main Epsom Creek Valley, and on top of the high bluffs of sandstone which border it for nearly its whole length, we found some cave-houses in a most singularly out-of-the-way place—in the very last place in the world where one would expect to find them. Scaling the bluff at the very imminent risk of our necks, we came suddenly upon a broad open cave, near the top, containing the usual style of stone-built and mud-plastered houses, divided into four or five apartments, of just the size and number that would be required by an ordinary family of eight or ten persons. On top of the bluff we found the remains of a very old circular tower 40 feet in diameter, the stones all crumbled, rounded, and moss-covered. Near by were remains of two other cave-habitations.

* Report of Lieut. J. H. Simpson of an Expedition in the Navajo Country. Ex. Doc. No. 64, 31st Congress, 1st session.

A few miles farther up the Epsom Valley, passing a number of old ruins hardly worthy of mention, we came upon an important group, that was evidently the centre of the surrounding population—a place of worship or of general congregation—an aboriginal shire-town.

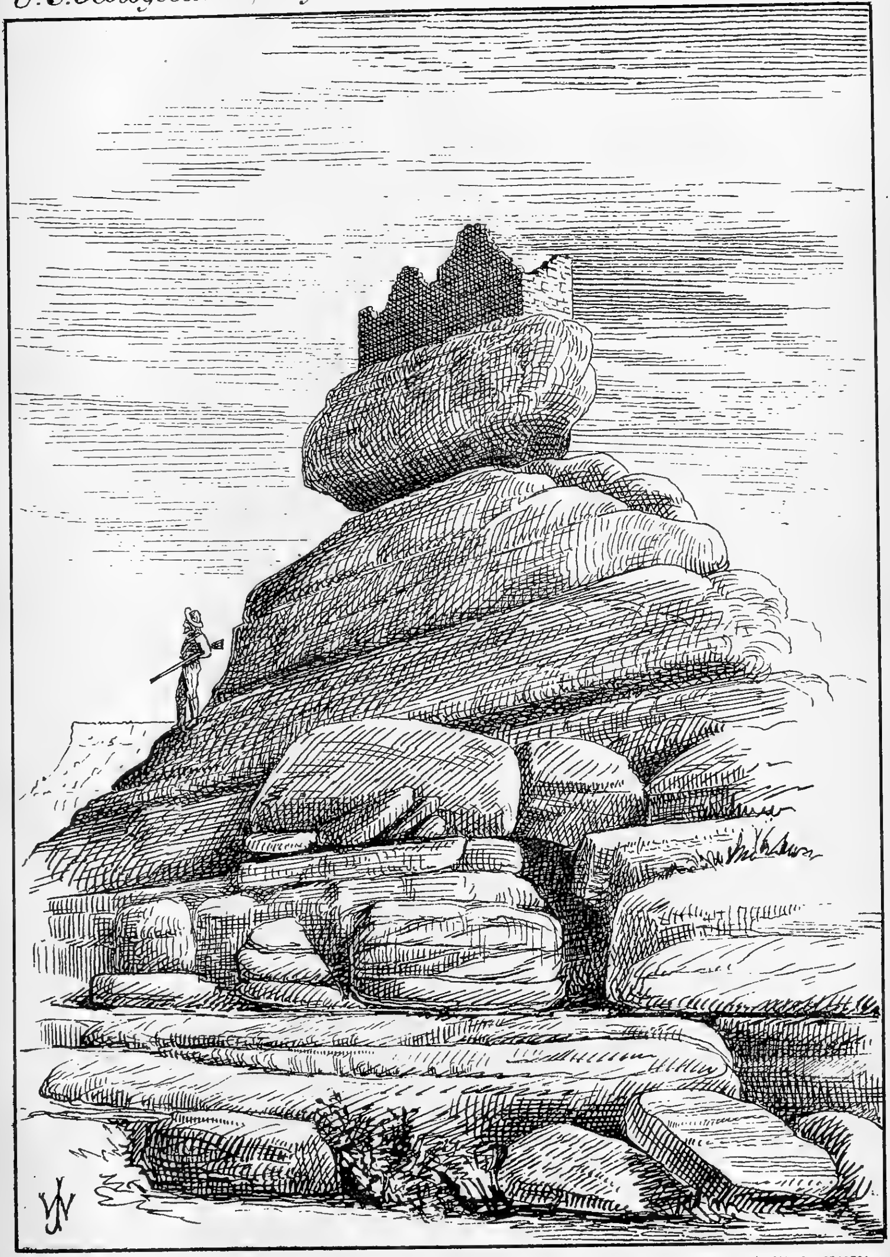
It lay upon both sides of a small, dry ravine, some 20 or 30 rods back from the bed of the creek, and consisted of a main rectangular mass, 60 by 100 feet square, occupying quite an elevation, dominating all the others. Just below it, and close upon the edge of the ravine, was a round tower 25 feet in diameter; and 75 feet below that, and also close to the ravine, was a square building 20 feet across, nearly obscured by a thicket of piñon-trees growing about it. On the opposite bank were two small round towers, each 15 feet in diameter, with two oblong structures between, 12 by 15 feet. At right angles to these four, which were arranged in a straight line, another square building occurred, the same size as the one just opposite on the other bank. Portions of the walls of the towers and a few courses of stone in the walls of the smaller square buildings remained, but in the large ruin the walls were merely indicated by great mounds of crumbling rock, with, however, the subdivisions distinctly marked into four rectangular apartments. A short distance above plenty of water was found in the bed of the creek; fine, large cottonwoods bordered the stream, and the broad, fertile valley seemed a far more desirable place of residence than the forbidding desolation of the Chelly.

About thirty miles from the San Juan we left Epsom Creek, and stopped for a night at the head of the cañons which run between it and the Montezuma. We were in the midst of quite a thickly-settled, ancient population, the ruins of their habitations consisting almost entirely of the kind just described—low, rectangular mounds, the original structures so completely destroyed as not to leave one stone upon another, yet accompanied always by an abundance of the same kind of pottery we have found so universally distributed over other localities. Not the slightest difference can be detected in its general quality, nor can any one style of manufacture or ornamentation be said to be peculiar to any one district or group of ancient habitations. It is the same with arrow-points and like work. The similarity of the workmanship exhibited in the cliff-houses, and also in the more extensive structures of the lowlands, although covering in all probability two different periods of their existence, convinces us that the builders were all one and the same people, scattered in families and communities throughout the valleys and cañons.

After leaving this last group of ruins, all traces of them suddenly ceased, and in the four or five days spent in the examination of the country upon the southern, eastern, and northern flanks of the Sierra Abajo, not a single vestige was found; and this in, without exception, the most pleasant spot we have touched since leaving La Plata. Clear and cold mountain-streams ripple down through ravines overhung by groves of willow, maple, and quaking-aspen, with splendid oaks and stately pines scattered over the uplands, and an abundance of rich, nutritious grass everywhere, that our poor, half-starved animals knew well how to appreciate. The black-tail deer and grouse were in goodly numbers, starting up from under our very noses, and leading our hunters many a long chase.

Leaving half of our little party of six, and all the animals but those we rode and the trusty Mex. with the apparatus, we made our way down through the deep and narrow cañons that lead from the plateau country into the great basin that lies between the Sierra Abajo and the

Plate LI.



AM. PHOTO-LITHO. CO. N. Y. (OSBORNES PROCESS.)

Sierra La Sal, and spent two days in the examination of its arid surface, which is covered with monumental rocks and ridges, but without coming across so much as a piece of pottery or an arrow-point.

RUINS OF MONTEZUMA CAÑON.

Turning our backs upon the Abajo Peaks, we struck out northeasterly over the plateau, but soon finding a trail bearing southeast, followed it until we saw that it was likely to continue some time upon the plateau, when we branched off to the left, and in a short distance came upon the very brink of the deep cañon of the Montezuma, one of the far-reaching arms of the main wash and valley farther east. Winding our way among rocks and scrubby piñons, we almost literally tumbled down the precipitous descent of 1,500 feet, to a narrow bottom, walled in first by a broad belt of massive white sandstone, rising almost perpendicularly from 20 to 50 feet above the valley; above that the dark red and shaly sand-rocks rose up in receding benches 1,000 feet to a broad tablet of white sandstone on top, so high up that it seemed to shut out all the world and to leave us as engulfed in the bosom of the earth. A narrow but deep "wash" meandered from side to side, containing just a few scattered pools of stagnant water, while dense thickets of oak brush, thickly interwoven with vines, rendered progress anything but pleasant.

We had gone but a few rods before we commenced picking up pieces of pottery and meeting other evidences of former occupation. Within three miles a cave-shelter appeared, and then as the valley widened it was dotted in many places with mounds thickly strewn over with the ever-accompanying ceramic handiwork of the ancient people in whose footsteps we are following, which occurred so frequently and to such extent as to excite astonishment at the numbers this narrow valley must have supported. The line is so sharply drawn that in an hour's ride all traces of any ruins are lost; and there is not so much as a piece of pottery to show that these people had ever extended their residence beyond the limits of their cañon.

Soon other cave-dwellings appear, most of them little walled-up circular orifices in the rock, generally inaccessible, but many were approached by steps, or rather small holes cut in in such a manner as to enable the climber to ascend the rock as by a ladder. Two examples of these kinds of ruins were noted, each about 40 feet above the valley, the first perfectly inaccessible and without the least sign of the original method of reaching it; in the other one the walls once closing it have been pushed down so that only traces of them remain; the steps leading up, however, show it to have been considerably used; they are now so worn down by the disintegrating influences of time as to no longer answer their purpose.

Throughout this cañon we find frequent examples of footholds cut in the rock, in the generality of cases being simply a way of scaling the smooth, nearly perpendicular wall of sandstone, which hems in the cañon on both sides for 12 or 15 miles; probably a ready mode of escape up the bluff should enemies appear.

The cliff and cave dwellings, very small habitations, appear to occur in groups, not always in connection with the old valley ruins, but rather alternate in succession as we progress down the cañon.

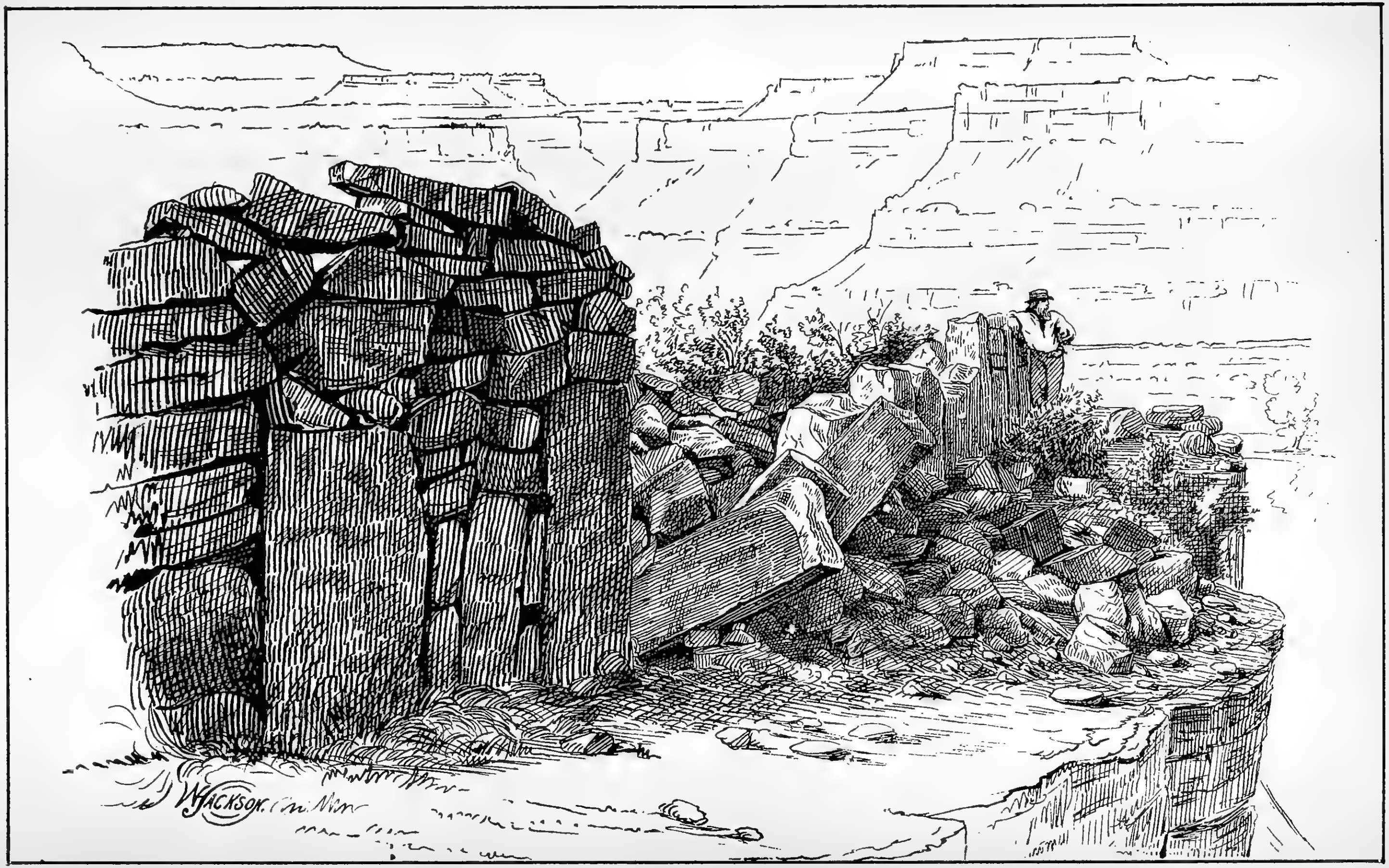
In one of the cave-dwellings, perfectly black with long-continued smokes inside, and bearing other marks of long use, we found the complete skeleton of a human being; the remains, as afterward determined, of a young man somewhat under a medium size. The excrement of small animals, dust, and other rubbish filled the floor of the little house

a foot deep, nearly burying the scattered bones; with them were the shreds of a woolen blanket, woven in long stripes of black and white, just such as the Navajos and Moquis make at the present time. It is likely that the remains are those of a Navajo, a people who occupied all this country up to within a short time, within the remembrance of the older persons, and who were driven beyond the San Juan by the onslaughts of the aggressive Utes.

After travelling about 20 miles from our starting-point at the foot of the mountains, half of the way in the cañon, we camped at the intersection of a large cañon coming in from the west, traversed by a large, well-travelled Indian trail, that continued on down, probably the same one we had crossed earlier in the day. At this point the bottoms widened out to 200 to 300 yards in width, and are literally covered with ruins, evidently those of an extensive settlement or community, although at the present time water was so scarce—there not being a drop within a radius of six miles—that we were compelled to make a dry camp. The ruins consist entirely of great solid mounds of rocky *débris*, piled up in rectangular masses, covered with earth and a brush-growth, bearing every indication of extreme age; just how old is about as impossible to tell as to say how old the rocks of this cañon are. This group is a mile in length, in the middle of the valley-space, and upon both sides of the wash. Each separate building would cover a space, generally, of 100 feet square; they are seldom subdivided into more than two or four apartments. Relics were abundant, broken pottery and arrow-points being especially plenty, and of excellent quality. At one place, where the wash had partially undermined the foundations of one of the large buildings, it exposed a wall of regularly-laid masonry extending down 6 feet beneath the superincumbent *débris* to the old floor-level, covered with ashes and the remains of half-charred sticks of juniper. From this rubbish a fine example of a stone axe, about the size of one's hand, was found, with a smooth and sharp cutting edge, formed by grinding it down to an acute angle; its head was roughly chipped to the required shape for binding on a handle. At another point a small earthen bowl, of the superior ware characteristic of the people, was found entire. No special burial-places were observed, but a number of bones of the lower extremities were unearthed at the edge of the wash, without any stone-work above them. There were no cave-dwellings in the neighborhood of this group, but two or three miles below several occured, one of which is built in a huge niche in the solid wall of the cañon, with its floor level with the valley.

From the last camp the cañon expanded into occasional valleys from 500 to 800 yards across, and then contracted to a mere narrow passage, but still all shut in by the high escarpment of the mesa. From either side long narrow tongues or promontories extend out 100 yards, and from 20 to 100 feet high, sometimes connected with the main wall by a mere comb or wall of rock, its extremity, however, spreading out to an irregularly oval shape. In the valleys are occasional isolated mesas, the remnants, probably, of former promontories, left here by the great erosive powers which channelled out these cañons. Within a distance of 15 miles there are some sixteen or eighteen of these promontories and isolated mesas, of different height, every one of them covered with ruins of old and massive stone-built structures. They will average in size from 100 by 200 feet square down to 30 by 50 feet, always in a solid block, and, with one exception, so nearly similar that a description of one will fairly represent all. This exceptional instance is explained in the sketch (Plate LII), and the ground-plan (Fig. 1, Plate XLVIII). The peculiarity here consists principally in the size and shape of the stones employed, as well as in the design of its ground-plan. The ruin occupies

Plate LII.



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)

one of the small, isolated mesas, whose floor is composed of a distinctly laminated sandstone, breaking into regular slabs from 18 to 24 inches in thickness; these have been broken again into long blocks, and then placed in the wall upright, the largest standing five feet above the soil in which they are planted. The sketch in Plate LII is a view along the line *a a a*, looking toward the round tower. Very nearly the entire length of this wall is made up of the large upright blocks of even thickness, fitting close together, with only occasional spaces filled up with smaller rocks. In one place the long blocks have been pushed outward by the weight of the *débris* back of it. One side of the large square apartment in the rear is made of the same kind of rocks, standing in a solid row. The walls throughout the rest of the building are composed of ordinary-sized rocks, with an occasional large upright one. Judging from the *débris*, the walls could not have been more than 8 or 10 feet in height. The foundation-line was well preserved, enabling us to measure accurately its dimensions. The large square room was depressed in the centre, and its three outside walls contained less material than in the rest of the building. No sign of any aperture, either of window or door, could be detected.

The far more numerous class of ruins occupying like mesas and the promontory points consist of a solid mass of small rectangular rooms, arranged without any appearance of order, conforming to the irregularities of the surface upon which they are built, and covering, usually, all of the available space chosen for their site. All are extremely old, tumbled into indefinite ridges 5 or 6 feet high, and as broad, with the stones partially crumbled into sand, and all covered with sage-brush, greasewood and junipers. They occupy every commanding and available spur of the mesas, usually so placed in the bends as to afford a clear lookout for considerable distances up and down the cañon. They resemble in this respect the sites chosen by the Moquis in building their villages; but we are not able to trace the resemblance further, from the extremely aged and ruinous state in which these remains are found. Between these fortresses and on the level bottom-lands, generally close up to the bluff upon either side, are occasional smaller ruins, resembling those at the dry camp. In connection with these a peculiar feature is shown in Plate LIII. At the foot of one of the promontory towns a low bench, tongue-shaped, and only about 10 feet above the valley, runs out from the mesa 200 feet in length and half as broad, through the centre of which runs a wall its entire length; a portion of it is composed of the large upright rocks shown in the sketch, the largest standing 7 feet above the surface and evidently extending some distance below, in order to be retained so firmly in their places. There are only seven of these standing, placed about 5 feet apart, the rest of the wall-line being composed of a low ridge of loose rock extending up to a mass of old ruins at the foot of the bluff. One side of the space divided by this wall is filled with a great pile of rocks arranged in irregular lines inclosing areas from 20 to 50 feet in diameter, the whole indicating a very considerable structure.

Grouped among the lower end of these towns were a number of the small cliff-houses; a regular colony of them occurring at the first bend of the West Montezuma, about a dozen miles above its junction with the east fork. An exceedingly well-preserved and peculiar one was noted. A block of sandstone setting on the edge of a mesa bench 50 feet above the valley has a deep oval hole worn in it, probably by natural agencies, which is nearly entirely occupied by a very neatly-built little house 10 feet long, 6 high, and 5 deep. A space at one end is reserved just large enough to serve as a platform from which to enter.

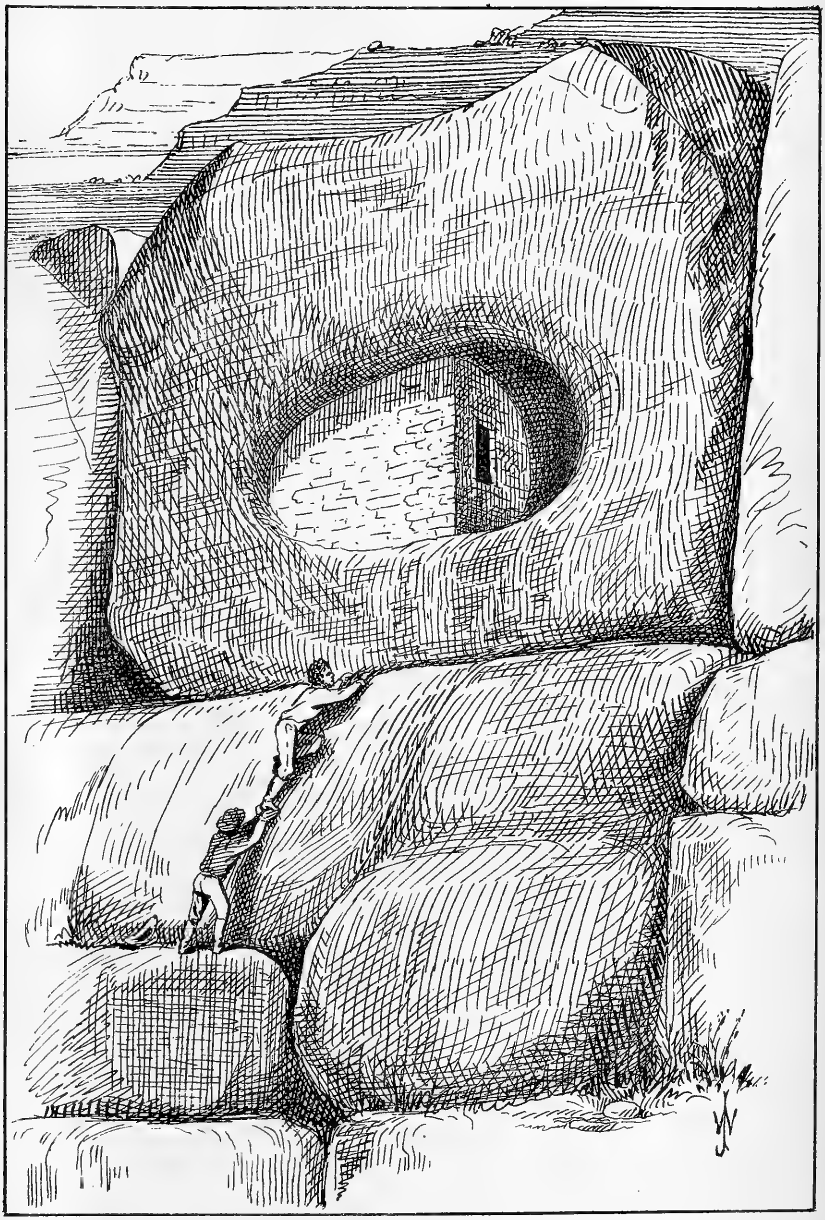
Below the bend in which these cliff-houses occur, the Montezuma loses its cañon character and spreads out into a wide, barren valley, thickly covered with tall sage-brush, and the wash is lined with large cottonwoods. The mesas upon either hand dwindle down considerably in height and abruptness, and seldom contain ruins. The large square buildings on the bottom-lands, however, are important features, and were it not for their great number, and the exceeding indefiniteness of their outlines, we might linger longer and describe each in detail. About all are found immense quantities of broken pottery, many examples of which are shown in the accompanying plates. Arrow-points and like chipped work were especially numerous, and a great many of small size and great delicacy of finish were found.

It should have been mentioned that running water occurs in the Montezuma at the bend spoken of, and a band of Weminuche Utes, who now occupy these cañons, have considerable corn planted there. It is not impossible that formerly water was constant throughout the whole length of the region occupied by these ruins. Below the junction of the east and west forks of the Montezuma, the valley must have been always hopelessly barren and dry, for not a vestige of any ruin occurs. At its mouth and along the San Juan, as we have noticed, they appear at once again in considerable numbers.

Our investigations closed with a side trip up into some of the sterile gorges between the two forks of the Montezuma, but without any results worth especial mention. A few small cliff-houses occurred, and a few scattered remains about the open lowlands. Upon the tops of the mesas in this vicinity, as well as upon those between the Montezuma and the Hovenweep, were old remains of towns. A glance at the accompanying map will give some idea of their distribution, although those about the head of the West Montezuma are only located approximately, in the absence of any precise notes of its topography.

Plate LIII.

AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

CHAPTER II.

RUINS OF THE CHACO CAÑON, EXAMINED IN 1877.

INTRODUCTION.

The great ruins in the Chaco Cañon, in Northern New Mexico, are pre-eminently the finest examples of the numerous and extensive remains of the works of unknown builders to be found north of the seat of the ancient Aztec Empire in Mexico, and of which there is comparatively but little known even to this day. The first published account which ever appeared in regard to them is a short reference to the Pueblo Bonito by Gregg in 1844.* His observations covered a period of eight years previous to 1840. In 1849 a military expedition under the command of Colonel Washington, then military governor of New Mexico, was sent against the Navajos, who were troublesome at that time, and their line of march traversed a portion of the cañon. The report of Lieutenant Simpson,† of the United States Topographical Engineers, who accompanied the expedition, contained the first detailed and authentic account ever published of these wonderful ruins, and it has been up to this time the only source of information.

Prof. O. Loew visited the Pueblo Pintado in 1874, and a short description of it by him appears in the annual report of the Chief of Engineers for 1875:‡

My visit to the cañon of the Chaco in the spring of 1877 (May 7–15) was made with no idea of discovering anything new, but to see for myself and thus be able to compare more satisfactorily the highest development of ancient architectural skill as exhibited in these ruins with the extensive remains in the San Juan basin, and also with the pueblos of New Mexico and Arizona which are still occupied. The results of the labor of four or five days spent in the examination of the eleven ruined pueblos that I saw are mainly condensed in the accompanying plates, and they will need but little explanatory text.

It was my intention to have reached the ruins from old Fort Defiance via the Cañon de Chelly and Washington Pass over the Tunecha Mountains, but I experienced so much trouble in securing the animals and

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* *Commerce of the Prairies.* J. Gregg. New York, 1844:

"Of such character are the ruins of the *Pueblo Bonito*, in the direction of Navajo, on the borders of the Cordilleras, the houses being generally built of slabs of fine-grit sandstone, a material utterly unknown in the present architecture of the north.

Although some of these structures are very massive and spacious, they are generally cut up into small, irregular rooms, many of which yet remain entire, being still covered with the *vigas*, or joists, remaining nearly sound under the *azoteas* of earth; and yet their age is such that there is no tradition which gives any account of their origin." (Vol. 1, p. 284.)

† Report Secretary of War, 31st Congress, 1st session, Senate Ex. Doc. No. 64.

‡ *Report on the Ruins of New Mexico.* By Dr. Oscar Loew, p. 184.

Professor Loew calls this the Pueblo Bonito. The account by Gregg, just quoted, evidently refers to the same ruin, as it is the first one approached from the east, and is some distance from the others, of which he probably knew nothing.

assistance necessary to the undertaking, that I deferred my visit until after my trip to the Moqui Pueblos in Arizona. It is somwhat singular that so interesting a region should be so little known, for but few of the persons residing about Defiance and Wingate have ever been to the spot or appear to know anything more than the fact of the existence of the ruins. Many of the Indians who reside near Defiance are familiar with the locality, but dread to visit it at this time of the year on account of the well-known dearth of water and of grass necessary to sustain their animals. Upon my return the same difficulty was met with again, but hearing of parties at San Ysidro that might assist me, I journeyed thither, and soon made an engagement with a Mr. Beaumont. He was not acquainted with the country beyond the Puerco, but, what served my purpose better, was a good interpreter. In the Pueblo of Jemez, three miles above San Ysidro, we found Hosta, the old ex-governor of Jemez, and the same brave-looking warrior whose portrait appears in Simpson's Journal. He accompanied that expedition as a guide, and was then spoken of as a fine looking and most intelligent Indian, whose vivacity and off-hand graciousness made him a great favorite. If his estimate of his present age is correct, he must have been upward of fifty years of age at that time, as he now shows every indication of bearing the four score or more years that he claims. His small frame is bent by disease and age, and his dim watery eyes look out through thin locks of straggling gray hair that but scantily cover his head. He declared himself, however, to be as good a man as any of us, and was at once ready to undertake the office of guide, stipulating only that his grandson, a lad of twelve or fifteen years, should accompany him, merely for the use of his eyes, as his own were failing and he feared he should not be able to recognize distant landmarks.

The trader's store at Jemez furnished us the only means of outfitting short of Santa Fé or Fort Wingate, but we did not need much, and all our supplies were packed upon one mule, the three besides myself who constituted the party riding the same useful animals.

Starting out early on the morning of May 7, our first day's journey brought us to the bridge over the Puerco, near the Cerro Cabezon. Late rains had filled its usually dry bed with such a flow of water that we judged it unwise to attempt any ford, and we knew of no bridge above this one, otherwise it would have been a much more direct course to have followed approximately the trail as laid down on Simpson's map. From the bridge we first journeyed northward four or five miles, then, entering a narrow cañon, bore off northwesterly, and, after crossing a low divide, came in about four miles more to the Cañada del Lumbre, in the bed of which we found a few pools of water. Crossing another low divide an hour's ride brought us to the valley of the Torrejon. There is some good land here, which has been utilized, as long as Hosta can remember, by the Navajos, for planting corn. Occasional cottonwoods line the banks of the dry arroyo, and impart a little freshness to an otherwise desolate monotony. Two miles above where we came into the valley, are a number of large water-pockets, the work of the agriculturists, who are now just beginning to break the soil. Four or five miles beyond this point the valley narrows to a cañon and the dry arroyo increases in depth so that it is difficult to cross. In this we were finally compelled to make our camp, as it afforded the only grass for our animals, an accidental pool furnishing the necessary water.

After an hour's ride on the following day we left the Torrejon to our right, where a broad open valley opened out to the north, and kept on in our almost due northwest course, rising almost imperceptibly over a

comparatively level country to the Continental divide. On our right hand were several prominent mesas and some small conical buttes, otherwise the near landscape presented no marked features. In the extreme distance, however, the Cerro Cabezon, the San Mateo, and the Jemez Mountains were almost constantly in full view. The transition from the drainage of the Rio Grande to that of the Rio Colorado is so nearly imperceptible, that we could not tell within several miles where the true divide lay. Everything about us indicated that we were travelling upon the summit of a high plateau, in which the cañons of the Chaco, Torrejon, and Largo have their origin in scarcely perceptible furrows. From the point where we left the Torrejon to where the Chaco fairly commenced is about 12 miles. There is here a broad valley, with every appearance of having been covered with standing water which had evaporated and left the surface covered with a thin layer of whitish clay, which has cracked and curled up into a thousand fantastic forms under the intense heat of the sun. Looking across its desolate waste a mirage danced constantly on the horizon, magnifying the insignificant sage bushes and the low, rolling hills into great oaks and distant mountains. After passing this plain the low hills upon either side converge in such a manner as to leave but a narrow passage between them, and here the bed of this arm of the Chaco first takes definite shape. From the summit of the hill on the right the first of the great ruins may be easily discerned with the naked eye some six or seven miles away. A short distance farther and we found some water-pockets formed by an obstruction in the bed of the arroyo. A few families of Navajos, with large numbers of sheep and some horses, were camped near by. The previous season they had planted considerable ground in corn, drawing off by acequias the water which occasionally finds its way into the arroyo, and flooding the loose, porous soil adjacent to it. By a little prudent forethought in storing water at the right time, they are enabled to reclaim what would otherwise be an unprofitable waste. While yet four or five miles away the ruins loom up prominently, resembling at this distance a ledge of dark-brown sandstone, and it is only when within less than a mile that we recognize its true character. We were fortunate enough to find a pool of shallow water and some good grass near the ruin. The arroyo itself, which is here some 10 or 12 feet deep, was perfectly dry, the little depressions in the grassy soil of the level valley retaining water much longer than the bed of the streams.

THE PUEBLO PINTADO.

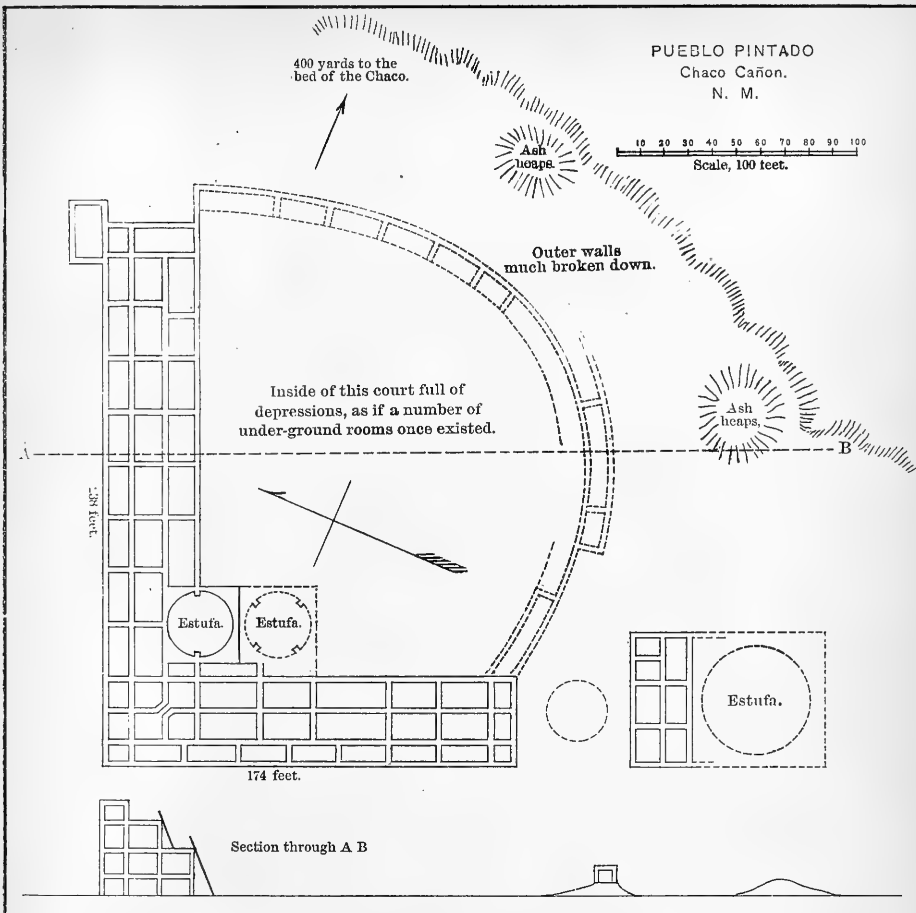
The ruins of the Pueblo Pintado* occupy a bench of some 25 or 30 feet elevation above the valley where we are camped, and this bench runs back into rolling hills and mesas covered with juniper and piñon trees. On the side of the bluff facing the valley is an outcrop of a yellowish-gray sandstone, showing in some places a seam of from 12 to 18 inches in thickness, where the rock breaks into thin slate-like layers. It was from this stratum that most of the material in the walls was obtained.

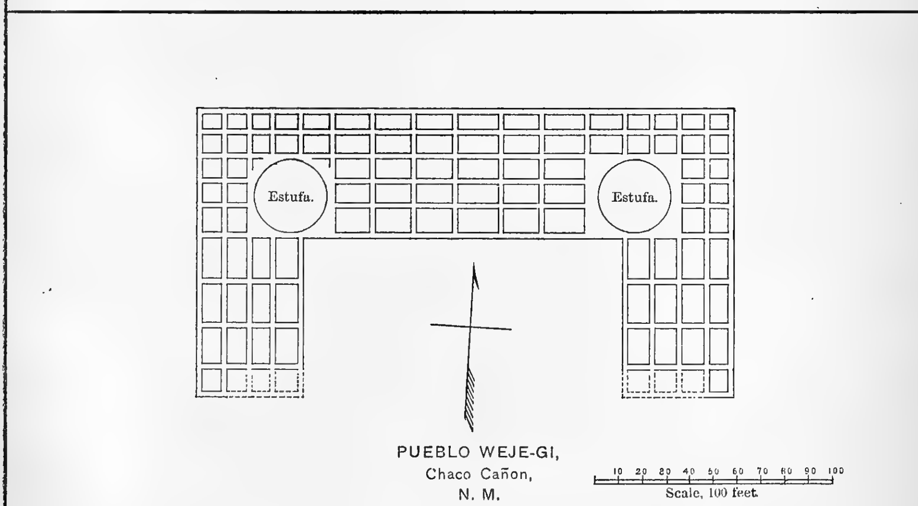
* This is the one undoubtedly referred to by Gregg as the Pueblo Bonito. Professor Loew refers to it under the same name. I have, however, adopted throughout the names given by Simpson. He thus refers to this one. It is "called, according to some of the Pueblo Indians with us, *Pueblo de Montezuma*, and according to the Mexicans, *Pueblo Colorado*. Hosta calls it *Pueblo de Ratones;* Sandoval, the friendly Navajo chief with us, *Pueblo Grande;* and Carravahal, our Mexican guide, who probably knows more about it than any one else, *Pueblo Pintado*." It will readily be inferred from the above that none of these names give any indication whatever of those in use during the occupancy of the pueblos.

Referring to the ground plan (Plate LV), which is the result of careful measurements carried mainly over the floor of the second story, it will be seen that the principal portion consists of an L shaped building, the two wings of which, facing south and east within 20 degrees, measure upon their exterior surfaces 238 and 174 feet. The extremities of these wings are connected by a wall or row of small houses springing in an arch from one to the other. Many of the small apartments in this row have their walls so well preserved that they can be readily measured.

Almost the entire area of the court thus enclosed, approximately 200 feet by 160 feet, presents a very irregular and broken surface, as though it had been nearly all occupied by underground apartments, the roofs of which falling in produced the great depressions and mounds which now exist. The two outer walls, which are now standing in places about 30 feet in height, indicate an original elevation of at least 40 feet, unbroken by any apertures excepting the smallest kind of windows. The northern walls presents the largest unbroken surface. The northwest corner and the western wall are much more broken down. The two interior longitudinal lines of wall in both wings are intact throughout most of their length to the top of the second and third stories, while the wall facing the court barely extends up into the second story. In the northwest angle of the court are two circular rooms or *estufas*,* the best-preserved one of which is built into the main building and forms a portion of it, while the other stands outside, but in juxtaposition, and is evidently a later and less perfect addition. They are each 25 feet in diameter. The inside walls are perfectly cylindrical, and in the case of the inner one are in good preservation for a height of about 5 feet. The bottom is filled with *débris* which must be of nearly the same depth. Two counter-forts or pillars of masonry of the same character as the rest of the room are built into the circular wall, bisecting it on a line the continuation of which forms the inside front wall of the north wall. They are 22 inches square, and extend about 2 feet above the present floor; there are no indications in the wall that they had ever been much higher. The outer *estufa* is much more ruinous, small portions only of its inner walls remaining intact. This has four equidistant counter-forts, but they are placed diagonally with the square which encloses the circle instead of at right angles to it, as in the case of the first one. Both rooms are enclosed within squares, the space between the circular rooms and the enclosing squares being filled in with solid masonry. The one around the outer *estufa* is entirely ruined, while that about the inner one is in very good preservation. There are no side apertures, so that light and access was probably obtained through the roof. These *estufas*, which figure so prominently in these ruins, and in fact in all the ancient ruins extending southward from the basin of the Rio San Juan, are so identical in their structure, position, and evident uses with the similar ones in the pueblos now inhabited, that they indisputably connect one with the other, and show this region to have been covered at one time with a numerous population, of which the present inhabitants of the pueblos of Moqui and of New Mexico are either the remnants or the descendants. Among the modern pueblos, some of these *estufas* are either round or square subterranean rooms apart from their dwellings; while among others they are simply large rooms, not otherwise distinguishable from the living-rooms in the main body of the building.

**Estufa* is a Spanish word, the literal translation of which, as here applied, is a sweat-house. This is true in but a limited sense. They are more properly council-rooms, to which the men retire for deliberation, and for the observances of their pagan religion. No name has been coined which better expresses their character; hence the above has obtained general application.





M. JOYCE, WASHINGTON.

Besides the two *estufas* within the court, there is another just outside at the southwest corner, fully 50 feet in diameter, enclosed within a rectangle measuring 56 by 80 feet. Twenty-four feet of one end of this is divided into six or seven apartments. These are exactly opposite the end of the west wall, with a passage-way of about 50 feet between. In the centre of this space is a depression and other indications of what was probably an underground room. Besides the three circular rooms just described, which were not in reality subterranean, there were undoubtedly many others within the court, as already conjectured, which were. These may have been simply underground work-rooms. Among the Moquis it is a common practice for both men and women to resort to the underground rooms or *estufas* to work at their looms or other similar occupation, as they are delightfully cool during the hot, burning days of summer, and warm and comfortable in the winter. Beneath the ground plan in Plate LV is a section through a restoration of the pueblo from north to south, showing the manner in which the stories were probably terraced from the interior of the court outward. There is no positive evidence in any of these ruins that they were thus built, but this arrangement naturally suggests itself as being the only way in which light and ease of access to the inner rooms could be readily obtained. It is also quite certain from the character of the standing walls that they were not terraced symmetrically, but irregularly, after the manner of the present pueblos. There is every reason to believe that the first story was in every case reached from the outside by ladders, the succeeding stories being also approached from the outside, either by ladders or by stone stairways, after the manner of the Moqui pueblos. There is no positive evidence to sustain any conjecture upon this point, as in every ruin the upper stories are so entirely dismantled that no indications of any sort of stairway have ever been found. The ground floor was divided into smaller apartments than the second floor, many of the rooms, as shown in the plan, being in the lower story divided into two or three. It would be impossible to say how high this story had been, as the floor is covered to a considerable extent with stones from the fallen walls. The second floor was 10 feet between joists, and the third somewhat less, about 7 feet, as near as we could judge from below. It is probable that there was a fourth story, but there is now very little evidence of it. Not a vestige of the *vigas* or other floor-timbers now remain. Some of the lintels over the doors or windows, composed of sticks of wood from 1 to 2 inches thickness, laid close together, are now in fair preservation.

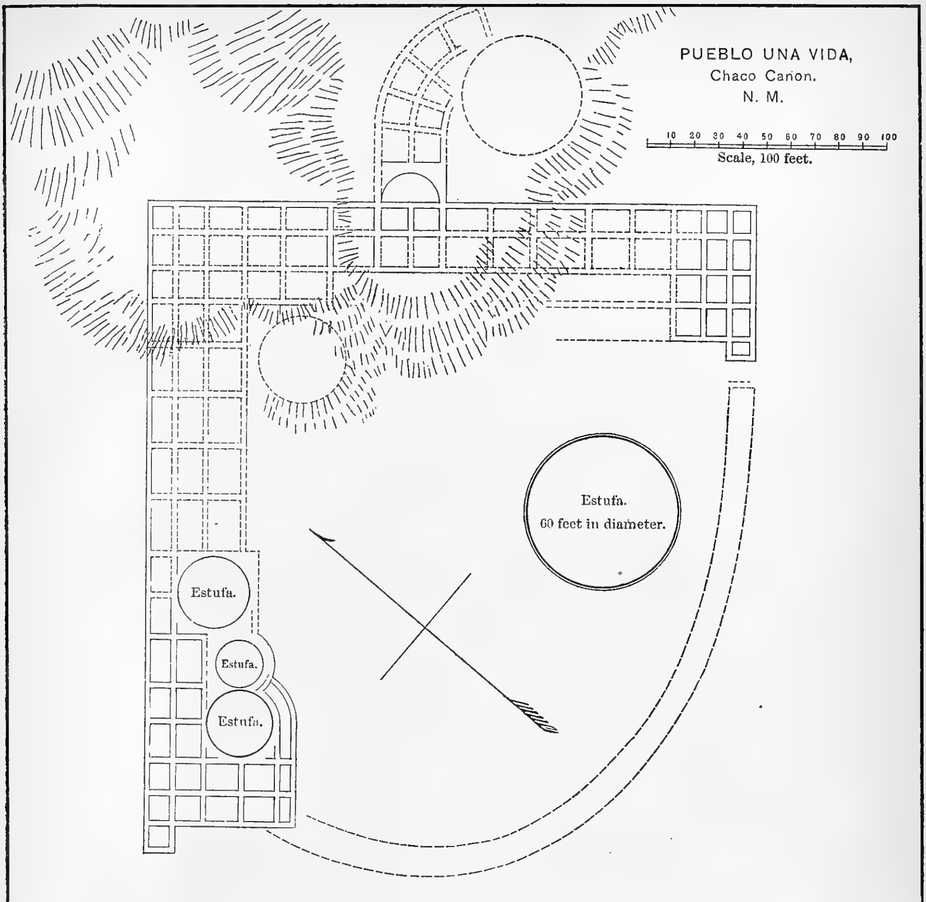
Hosta states that the soldiers of Colonel Washington's command and of other scouting parties caused a great deal of the present ruin by pulling out the floor-timbers for their camp-fires. He also says he can distinctly remember when there were a number of perfect rooms. Every room had one or more apertures, in the form of small window-like doorways, the largest of which are 24 by 40 inches, leading into neighboring rooms. The sills of these doors are generally about 2 feet above the floor. In the west wall are several large windows looking outward from the second story, and in the north wall very small ones only in the second and third stories. There were a few very small apertures in the first story, mere peep-holes. The walls of the first floor are 28 to 30 inches thick, those of each ascending story being a little less. The masonry, as it is displayed in the construction of the walls, is the most wonderful feature in these ancient habitations, and is in striking contrast to the careless and rude methods shown in the dwellings of the present Pueblos. Those of Moqui, Taos, and probably Acoma, were in

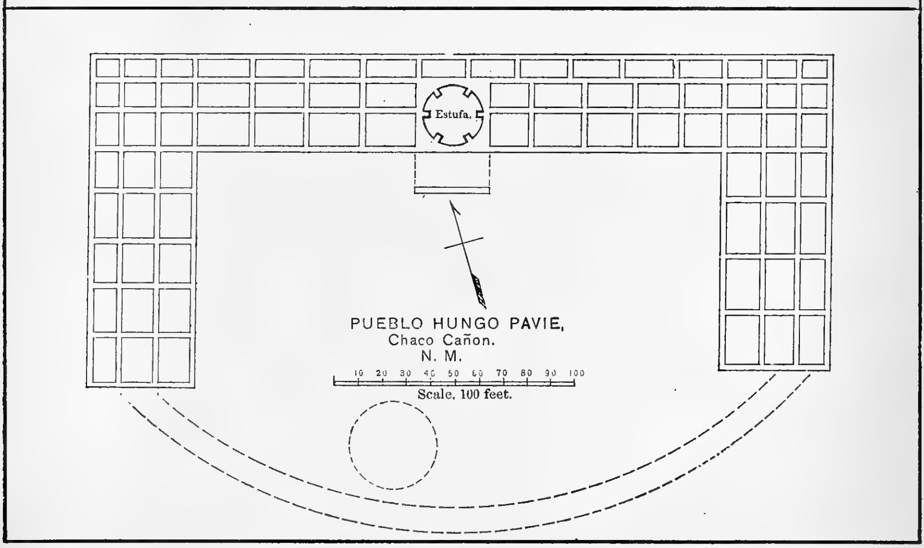
no better condition when first discovered by the Spaniards, nearly three hundred and forty years ago, than they are now, and how much older these perfect buildings were then than the rude piles of adobe and uncut stone found by the first conquerors, the past can only tell, and that is dead and buried. The material, a grayish-yellow sandstone, breaking readily into thin laminæ, was quarried from the adjacent exposures of that rock. In the ruin it has weathered to a warm brown, so that at a distance it looks almost black. The stones employed average about the size of an ordinary brick, but as the larger pieces were irregular in size, the interstices were filled in with very thin plates of sandstone, or rather built in during its construction, for by no other means could they be placed with such regularity and compactness. So closely are the individual pieces fitted to each other that at a little distance no jointage appears, and the wall bears every indication of being a plain solid surface. A clay mortar was used plentifully within the body of the wall but does not appear anywhere upon the surface. Great pains were taken in the construction of the door-ways, the stones being more regular in size and the corners dressed down to perfect right angles; the same care was given to the openings in the lowest floor as to those in the upper. In the northwest corner of the main building, back of the *estufas* and on the second floor, a door-way has been constructed leading diagonally from one room to another, which displays particularly nice workmanship. The lintels were in nearly every case composed of small round sticks of cedar or pine placed in contact, but in the smaller openings were formed by a single slab of stone. Although there is a great diversity in the size of the stones employed, still they are ranged in perfectly horizontal layers, rows of the larger stones alternating with rows of smaller ones, presenting at a little distance a beautifully laminated appearance.

In regard to the number of inhabitants, I do not think there were more than about 200. There are 51 rooms on the second floor, exclusive of the *estufas* and outside buildings. The lower floor was composed of a larger number of rooms, and the third floor of a less number, so that in the whole building there are probably about 150 apartments. Divide occupants into families and each would occupy on an average four rooms, and then if we allow five persons to each family we have 200 souls in all, as estimated.

Upon the southeastern front, just outside of the court, are two rubbish-heaps, the refuse carried out and there deposited by the ancient occupants. Throughout the mass are large numbers of fragments of painted pottery and flint-chippings, but nothing of any greater interest was found in the limited time at our disposal. The trail here leaves the arroyo of the Chaco to avoid a considerable bend which it makes to the right. The surface is slightly undulating, and in the neighborhood of the trail, both above and below the Pueblo, is covered with a number of small old ruins. I counted ten such within a mile of each other. They are built of stone, of but one story, and varied from 30 to 50 feet in exterior dimensions.

Two miles from the ruin we descended into the cañon of the Chaco. It is here only about 50 feet in depth, with vertical walls of yellowish-gray sandstone. The dry bed of the arroyo meandering along the bottom, almost entirely cuts off communication from one side of the cañon with the other. Numerous small cottonwoods attest that there is moisture somewhere in the neighborhood. A two hours' ride brought us to a few water-pockets or reservoirs in the bottom of the arroyo, in which was a plentiful supply of thick, pasty water. Some families of Navajos, with their sheep and goats, were camped near by.





M. JOYCE, WASHINGTON.

THE PUEBLO WEJE-GI.

Twelve miles from the Pueblo Pintado, and on the north side of the cañon, are the next important ruins, although we had passed several small ones on the way. The Pueblo Weje-gi, as Simpson calls it, is situated close under the bluff, and is a rectangular structure built around three sides of an open court which faces almost due south. Its exterior dimensions are 224 by 120 feet. The walls are still standing to considerable height and indicate at least three stories. They are built in much the same style as those of the Pueblo Pintado, of small tabular pieces of sandstone arranged with a beautiful effect of regularity and finish. This ruin is remarkable for the perfect symmetry of the arrangement of the rooms and of the *estufas*, a close scrutiny and careful measurement failing to detect any deviation. The rooms are small, the largest being 8 by 14 feet and the smallest 8 feet square. The *estufas* are each 30 feet in diameter and are placed just within the two elbows of the building.

There is not the least indication of the court ever having been enclosed by a wall. None of the wood-work now remains in place. The outer walls, like those in the first ruin described, were built up to the full height of the building, and were without any aperture save the smallest kind of windows.

PUEBLO UNA VIDA.

Two miles and a half farther down the cañon, and also on the north side, are the ruins of the Pueblo Una Vida. At this point the cañon bends to the northwest around a promontory at the foot of which are the ruins. On the opposite side there is a break for about half a mile in the bluffs, which have completely shut us in thus far, in the centre of which space stands a remarkable butte or mesa some 300 feet in height. In the gaps between the butte and mesa we have fine distant views of the snow-crowned Sierra San Mateo, or Mount Taylor. The cañon is here about 500 yards wide, and is perfectly level from one side to the other. The bed of the stream is a perfectly dry wash, without even an occasional pool, except where it has been secured by artificial means, as at the place six miles above where the Indians were camped. Lieutenant Simpson passed through the cañon in August, and mentions that at this place there was a width of 8 feet, and a depth of 1½ feet of running water in the arroyo. It was then in the midst of the rainy season, however; but heavy rains had fallen over this part of the country a few days previous to our visit, yet it appeared as if it had been subjected to a prolonged drought.

The Pueblo Una Vida resembles in its ground plan quite closely that of the Pueblo Pintado. It has the same L-shaped main building, the two extremes of which are connected by a semicircular wall. The two wings facing within a few degrees south and east respectively, are 274 and 253 feet in length; the longer one running north and south over a slightly rising surface, while the other, which is at right angles to it, runs over a rocky knoll some 15 or 20 feet above the general level. Within the enclosure are the remains of the largest *estufa* to be found in any of the eleven great ruins. The inside measurement from wall to wall is 60.2 feet; the masonry of the cylindrical surface is perfect throughout most of the circle, and is in places four feet high, its upper edge on a plane with the floor of the court; it was evidently entirely subterranean. In the southern end of the longest wing are three other *estufas*, their interior walls in good preservation, the diameters of which are

respectively 28, 18, and 30 feet. Midway its length, and back of the other wing, is a semicircular apartment, the outside walls being rectangular, the inside diameter of which 12½ by 25 feet. Extending from this room toward the bluff, and at right angles to the north wing, are some lines of ruined walls, the details of which are nearly indistinguishable. I have drawn them as bending round towards a large circular depression which exists on the right hand, but it is possible that this appearance was caused by the way in which the walls fell, and that they were originally a portion of a rectangular extension.

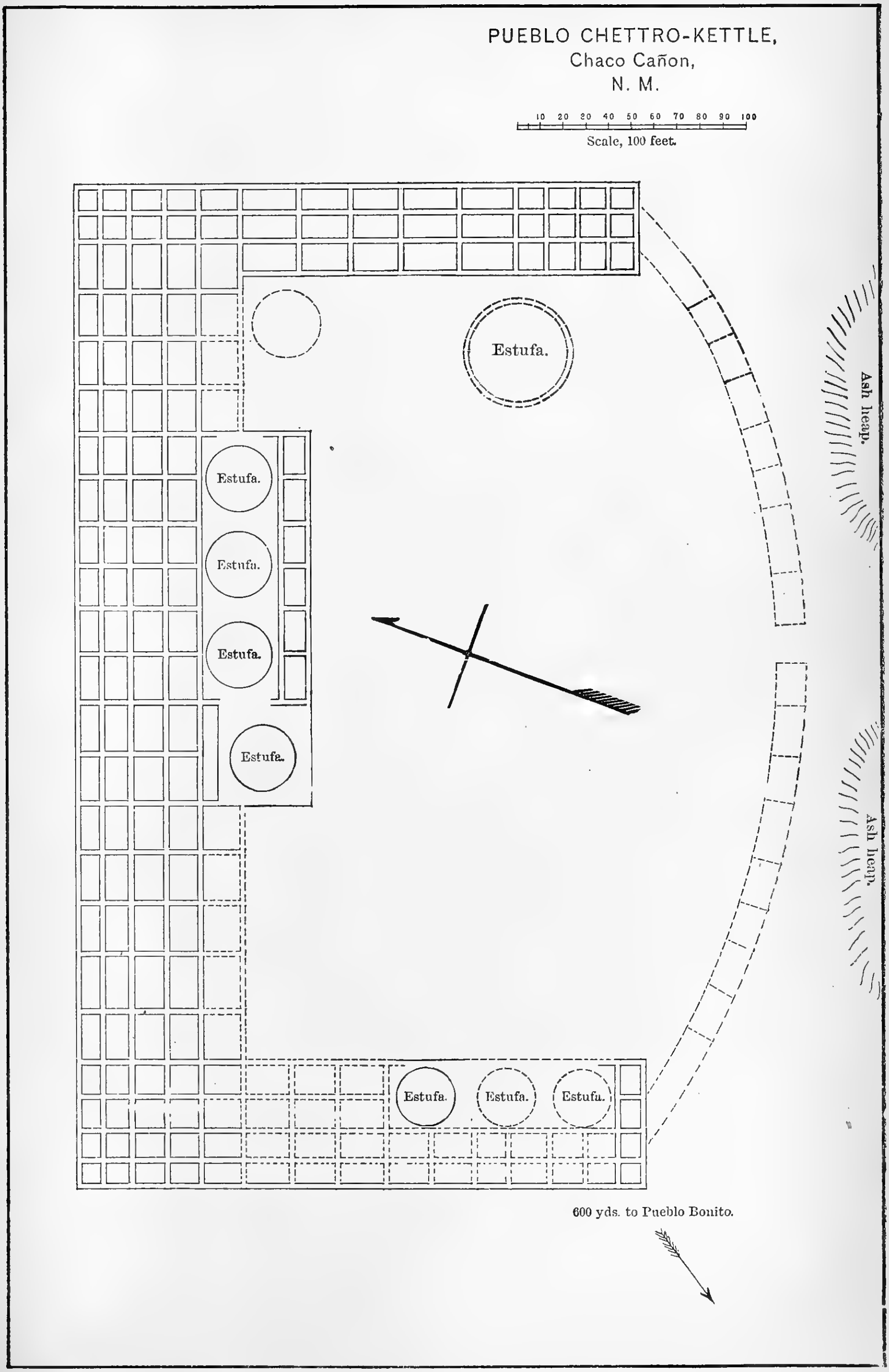
The ruins of the wall enclosing the court are low and broad, with but little masonry visible. The gate-way or entrance seems to have been at the right hand or upper end, just outside of which is a large rubbish-heap. The walls are in a much better state of preservation in the neighborhood of the three *estufas*. Everywhere else they are much ruined, particularly at the angle of the junction of the two wings, and the general appearance conveys the impression of a much greater age than any of the others, with one exception which will be noted.

PUEBLO HUNGO PAVIE.

One mile farther, on the same side and also built close under the walls of the cañon, are the ruins of the Pueblo Hungo Pavie, or Crooked Nose, portions of which are yet in quite perfect condition. It is built like Weje-gi around three sides of a court, but this is enclosed by a semicircular wall reaching from one wing to the other. The north or main building is 309 feet long on the outside, and the two wings 136 feet each. The ground plan represents a depth of but three rows of rooms, and as the walls still indicate that there were at least four stories, it gives a much greater degree of height in comparison with breadth than any of the other ruins. The single *estufa* is situated midway in the north building and appears to have extended up to the top of the second story. In front of it is a projection or platform of masonry, nearly as high and of the same width as the *estufa*, which extends some 10 or 12 feet into the court. The interior, which is 23 feet in diameter, has six counter-forts or square pillars of masonry—like those of the Pueblo Pintado—built into the encircling wall at equal distances from each other, and which appear to have extended up to the top. In the northeast corner of the ruins the walls are now standing 30 feet high, showing a portion of the fourth floor. Many of the heavy pine logs that supported the flooring are still in position. The height of the second-story rooms was about 9 feet and of the third-story about 7 feet. The masonry is of the same character as that already noticed, but the walls of the first story are of unusual thickness—nearly 3 feet—otherwise it has no marked difference of features. The rooms of the central portion of the building are generally long and narrow, while those of the wings are of the same length but wider. There are no signs of masonry in the low mound which is all there is left of the wall which enclosed the court. Just outside of it, near the centre, is the usual mound of rubbish, and just inside, one of the great circular depressions generally found in the same relative position in nearly all the ruins.

PUEBLO OF CHETTRO KETTLE.

Two miles farther along under the northern wall of the cañon we came to the ruins of the great Pueblo of Chettro Kettle, or the Rain Pueblo. This is of the same pattern as the Pueblo of Hungo Pavie, and is the



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largest of the perfect rectangles. Its outside dimensions are 440 by 250 feet. A semicircular wall connects the two side wings. There are seven distinctly-marked *estufas*, four near the centre of the main building and three near the end of the west wing. Besides these there are indications of others within the court but outside the building. The four in the centre are built together in a solid body and project partially from the main building into the court; the one on the left projecting farther than the other three, which have a row of small rooms between them and the court. This left-hand *estufa* is also noticeable from its height, rising as it does above the general level of the ruin about it. It was originally divided into three stories, all above ground, and the remnants by the *vigas* between the first and second floors still remain in the wall. The three others were not so high and were probably not more than one full story in height. These four averaged 22 feet in diameter. The other three *estufas* in the west wing, which are much ruined, do not differ from others we have seen. The walls of the pueblo at the northeast corner are fully 35 feet in height, showing four floors plainly, and with indications that there may possibly have been another. Many of the floor timbers are yet in place, those that are in any way protected from atmospheric changes remaining quite sound. The entire series covering the rooms of the first floor project through the wall and extend beyond it 4 or 5 feet. It may have supported a balcony on this, the cool and shady side of the house.

The following is a description by Simpson of a room seen by him in this pueblo: "This room is 14 by 17½ in plan and 10 feet in elevation. It has an outside doorway 3½ feet high by 2¼ wide, and one at its west end leading into the adjoining room 2 feet wide, and, at present, on account of rubbish, only 2½ feet high. The stone walls still have their plaster upon them, in a tolerable state of preservation. On the south wall is a recess or niche, 3 feet 2 inches high, by 4 feet 5 inches wide by 4 feet deep. Its position and size naturally suggested the idea that it might have been a fireplace, but, if so, the smoke must have returned to the room, as there was no chimney built for it. In addition to this large recess, there were three smaller ones in the same wall. The ceiling showed two main beams laid transversely. On these, longitudinally, are a number of smaller ones in juxtaposition, the ends being tied together by a species of woody fibre, and the interstices chinked in with small stones. On these again, transversely, in close contact, was a kind of lathing of the odor and appearance of cedar, all in a good state of preservation." We did not find the room thus described, which was stated to be in the northwest corner of the ruins, but we found others near the centre of the north wing that were in as good a state of preservation and to which the above description applies, with the exception of some of the details. These were entered by holes that have been broken in the outer wall. At one time there has been a row of windows, about 24 by 40 inches in size, all along the first story. These, however, had been sealed up, but as all other approaches had been cut off by the great mass of fallen walls, which covered the regular approaches, some of them were reopened, probably not long ago.

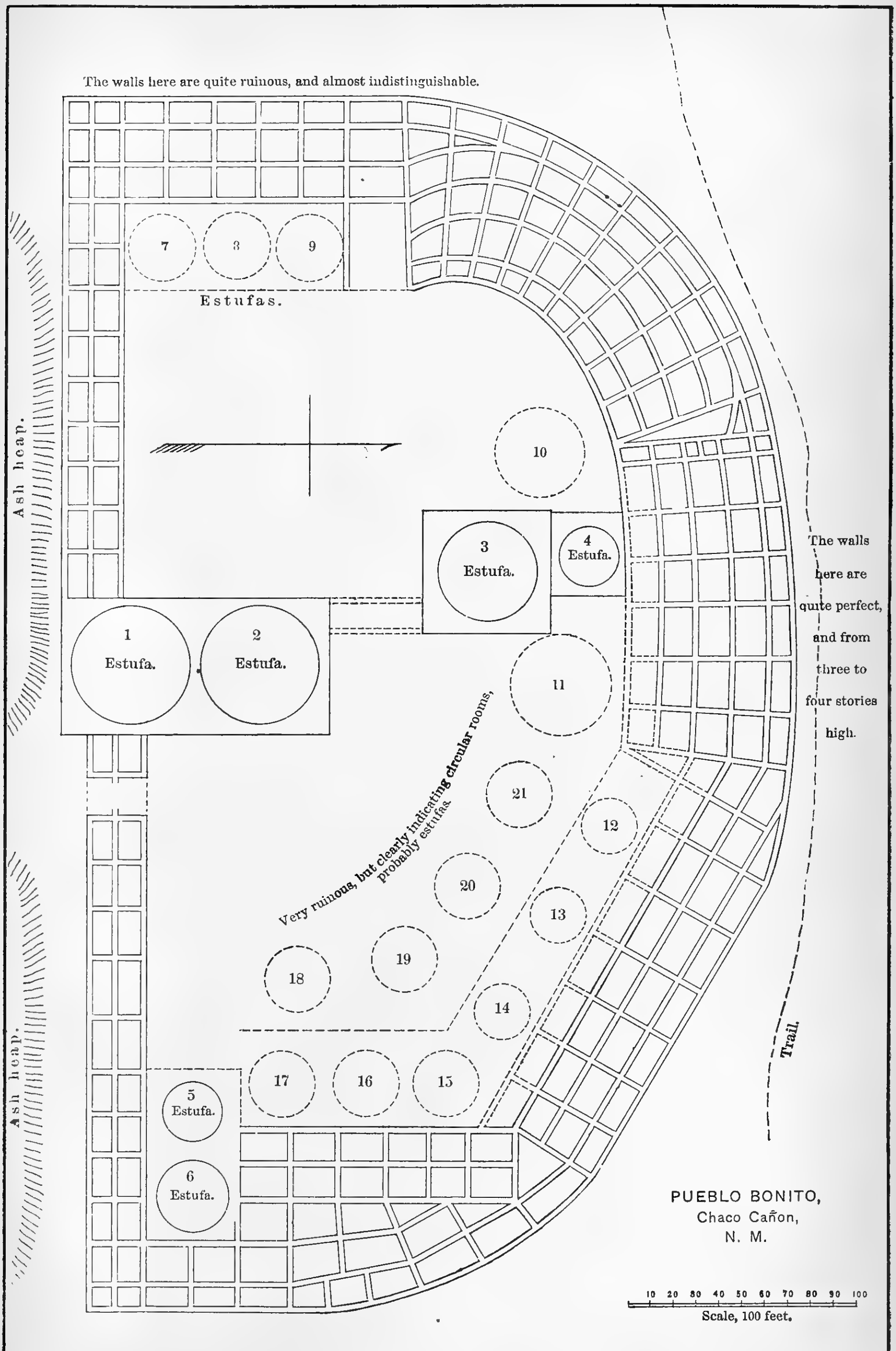
The general level of the sandy surface back of this ruin was nearly up to the sill of the windows and considerably above the floor of the lower rooms. The soil has undoubtedly increased considerably in depth from the accumulation of sifting sand and the disintegration of the high bluffs of sandstone, which are within a few yards of the rear wall. Near this wall a coyote hole exposed a small section of masonry below the surface, a portion of a wall or something of that kind, that had become entirely

covered up with sand. I was alone at the time, with no implement whatever suited to an excavation, or I would have investigated further. The masonry of this ruin is remarkable for the effect of fine finish imparted to its general appearance. It consists almost entirely of small tabular pieces of stone, although in some portions of the building the material is selected as to size, and laid in parallel courses. The exterior walls, however, are composed entirely of very small pieces, arranged without order, but so compactly and solidly as to give the impression of a homogeneous surface, and this is secured without the aid of any cement or adobe mortar appearing between the joints. I measured off at random a square yard on the back wall just behind the *estufas*, and found that 450 pieces of stone appeared on the surface within that space. The opposite surface was formed in like manner, but as these stones would form less than one-half the thickness of the walls, the rest was made up of larger and more irregular pieces laid in an abundance of clay cement. Imagine the industry and patience required to build such a wall.

In this ruin there was at one time a line of wall running around three sides of the building, 935 feet in length and about 40 feet in height, giving 37,400 square feet of surface, and as an average of 50 pieces of stone appeared within the space of every square foot, this would give nearly 2,000,000 pieces for the outer surface of the outer wall alone; multiply this by the opposite surface, and also by the interior and transverse lines of masonry, and, supposing a symmetrical terracing, we will find that it will swell the total up into more than 30,000,000, embraced within about 315,000 cubic feet of masonry. These millions of pieces had to be quarried, dressed roughly to fit their places, and carefully adapted to it; the massive timbers had to be brought from a considerable distance, cut and fitted to their places in the wall and then covered with other courses; and then the other details of window and roof making, plastering, and construction of ladders, must have employed a large body of intelligent, well-organized, patient, and industrious people, under thorough discipline, for a very long time. The remains of the wall that enclosed the court show it to have been of stone and to have been divided into apartments, for at regular intervals of about 10 feet there are lines of stone-work at right angles to its trend, the same as in two other ruins at least in which a number of these apartments are in good preservation, showing clearly their character. The centre was broken, as if for an opening or gateway, and upon either hand outside were long mounds of rubbish, the refuse of the town. Within about 20 yards of the northwest angle of the ruin, and built upon a slight mound at the base of the bluff, are the ruins of a structure that bears about the same relation to this pueblo as the similar one which appears in connection with the Pueblo Pintado. These adjacent structures also appear in connection with most of the ruins about to be described. Although very ruinous, enough remains to show the large circular room in the interior, with probably two or three other rectangular rooms.

PUEBLO BONITO.

Five hundred yards below and also close under the perpendicular walls of the cañon are the ruins of the Pueblo Bonito, the largest and in some respects the most remarkable of all. Its length is 544 feet and its width 314 feet. By referring to the plan it will be seen that it only roughly approximates the usual rectangular shape. The two side wings are parallel with each other, and at right angles to the front wall, for a



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distance of 70 feet; the west wing then bends around until a little past a line drawn through the centre of the ruin transversely, when it bears off diagonally to join the east wing, thus resembling in its outline a semi-oval. Instead of a semicircular wall, the court is enclosed by a perfectly straight row of small buildings running almost due east and west, and is intersected by a line of *estufas*, which divide it (the court) into two nearly equal portions. A marked feature is the difference in the manner of construction, as shown in the character of the masonry and of the ground plan. It was not built with the unity of purpose so evident in the Pueblo of Chettro Kettle and some others, but large additions have been spliced in from time to time, producing a complexity in the arrangement of the rooms difficult to follow out. I spent several hours in endeavoring to unravel the intricacies of the foundations, and with better success than I imagined possible. The left-hand wing consists of three rows of rooms, eight in each row, 12 to 15 feet wide and from 12 to 20 feet in length. The outer walls are entirely demolished, but some of the interior walls reach to the top of the second story. In front of this wing and facing the court are the remains of what were probably three circular, partially subterranean rooms, probably *estufas*. The section adjoining this wing is in the shape of an almost perfect quarter-circle, and consists of five tiers of rooms, with nine rooms in each. The walls are standing quite generally as high as the second story. The outer tier of rooms of this section, which are only about 4 feet in width, seem to have been built on merely to assimilate this portion of the building with the rest, for they are evidently of different periods. The middle section is the most ruinous of all, but the great depth of the *débris* which covers several perfect rooms indicates that it originally possessed an equal height with the adjoining walls. The outer wall thus far is entirely ruined, hardly a stone remaining in place, but in the section that lies between the central line of *estufas* and the right-hand wing it rises up to the fourth story, and is in a remarkably well-preserved condition. Portions of it are evidently a quite late addition in the history of the ancient pueblo, some of the outer rows having been spliced or joined to the last wing in a manner which will be better understood by a reference to the plate than by any description. Several of the interior parallel and transverse walls are also standing fully 30 feet high. Many of the *vigas*, which are in excellent preservation, still retain their places and protect a number of rooms on the first floor. The outer wall of the east wing is in fair preservation, while the interior walls are in excellent order for at least two stories; the apartments in this and in the adjoining section are of unusual size, and the walls of the ground floor are of a firm massiveness that has preserved them remarkably well. Within this wing are two *estufas*, one of which came up with and formed a portion of the second story. Across the front of the court there are two tiers of rooms about 25 feet in width, their fallen walls making a mound of *débris* 5 to 8 feet in depth, indicating that they were of considerable height. Every transverse wall could be easily distinguished. Interrupting this about midway is a solid parallelogram 65 by 115 feet in dimensions, in which are two *estufas* each 50 feet in diameter. A low mass of ruins connects these with two more somewhat similar *estufas* that adjoin the centre of the main building.

Having thus roughly sketched in the external forms of the ruin, I will devote some space to a description of some of its details.

The masonry, as exhibited in the construction of the walls, is quite dissimilar in the different portions, showing clearly that it was either built at different periods, or that it had been once partially demolished

and then rebuilt. The three kinds of masonary shown in plate LXIII, appear at various places throughout the building, and, in addition, there is considerable rough-laid plastered wall, like that which appears in many of the old ruins, and which is also characteristic of all the Moqui pueblos. In that part of the external wall which is now standing a different method of laying the stones is observed in each story. The first or lowest story is built in the manner of No. 2; the second as No. 1; while in the third story it is a repetition of the first. The straight row across the front of the court was built almost entirely like No. 2, and the buildings immediately adjoining partook of the same character. Most of the interior walls, especially in the east wing and the section adjoining it, were built in the manner of No. 1; but of larger stones. A large number of beams of wood were used to strengthen the walls; round sticks of 3 and 4 inches diameter were built into the wall transversely, the ends trimmed off smooth and flush with the two outer surfaces, and larger timbers of from 10 to 15 feet in length and 6 to 8 in diameter were embedded longitudinally. We observed these in the outer wall only. The *estufas* in this ruin form an important feature, both from their number, size, and the excellent manner in which most of them were built. Referring to the plan (Plate LVIII), the first that attract our attention are those in the centre, Nos. 1 and 2, which have been already referred to. Neither these, nor in fact any of the others, with the exception probably of some of the more indistinct ones, which are indicated by dotted lines, appear to have been subterranean. No. 3 is 40 feet in diameter and No. 4, 26 feet; both are considerably elevated above the general surface. The masonry in the circles of these four central *estufas* is yet perfect around their entire circumferences, and the only others in like condition are the two in the east wing, Nos. 5 and 6. Besides these six, there are at least fifteen others in various degrees of demolition. Nos. 7, 8, and 9 are unmistakably of the same character as the preceding, and also those numbered from 10 to 17; the last six especially, having considerable portions of their cylindrical walls remaining. The remaining ones have only great mounds of stones and earth to mark their sites. The interior of the court is very uneven, there being no level ground whatever. This, as in the case of the Pueblo Pintado, I think, indicates that it was occupied with many subterraneam rooms. There are a number of rooms, the coverings of which have resisted the great weight of fallen walls, and are now in excellent preservation. These do not differ materially from those already mentioned; and, as Lieutenant Simpson and Dr. Hammond describe two that are in this ruin with considerable minuteness, I will say but little in regard to them. In one of these, a small room in the outer tier of the north side, which we entered by a small hole which had been broken through the exterior wall, we found the names of Lieutenant Simpson, Mr. R. H. Keen, and one or two others, with the date, August 27, 1849, scratched into the soft plastering which covered the walls, the impression appearing as plainly as if done but a few days previously. The pueblo was built within about 20 yards of the foot the bluff, but a talus of broken rock occupies all of this space, excepting a narrow passage next the northern wall, through which the trail passes. To the east of this are the ruins of several small buildings built upon a bench close under the rocks. The bench has been extended some distance by a wall of 6 or 8 feet hight, built of alternating bands of large and small stones. A short distance beyond is a mass of ruins measuring 135 by 75 feet, in the centre of which are two circular rooms. From the east side of this a line of wall ran due south about 300 feet, meeting at a right angle another wall 180 feet in length, which was an extension of the south front of the pueblo.

PUEBLO DEL ARROYO.

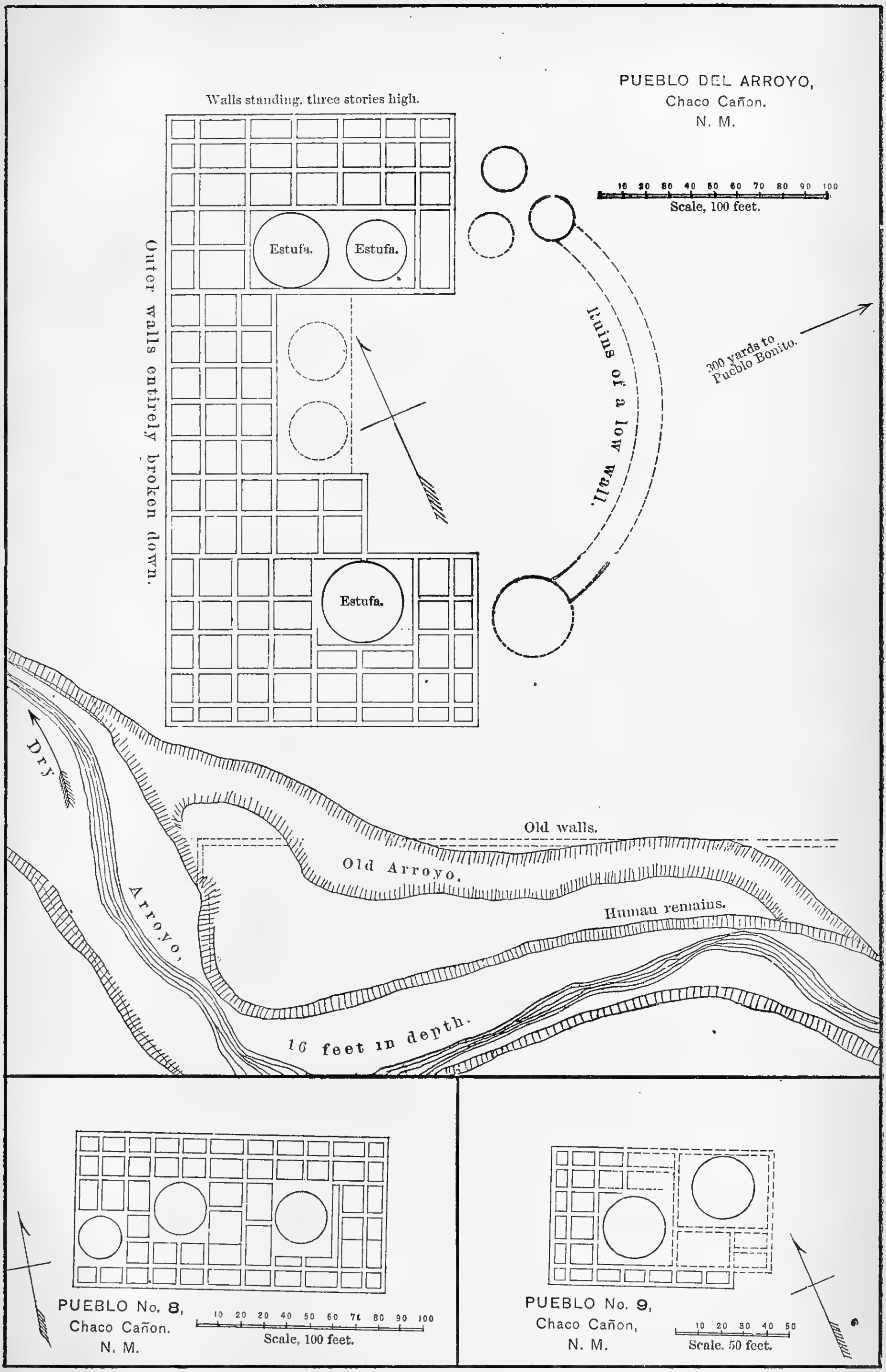
Three hundred yards below are the ruins of the Pueblo del Arroyo, so named probably because it is on the verge of the deep arroyo which traverses the middle of the cañon. This was given only a passing glance by Simpson, but it well repays more careful inspection. It is of the rectangular form, but with the open space or court facing a few degrees north of east. The west wall is 268 feet long and the two wings 125 and 135 feet respectively; their ends connected by a narrow and low semicircular wall. The wings are the most massively built and better preserved portion of the whole building; that portion which lies between them and back of the court being much more ruinous and dissimilar in many respects. The walls of the south wing, which are in the first story very heavy and massive, are still standing to the height of the third story. Many of the *vigas* are still in place, and are large and perfectly smooth and straight undressed logs of pine, averaging 10 inches in thickness; none of the smaller beams or other wood-work now remains. There is one *estufa* 37 feet in diameter in this wing. In the north wing the walls are standing somewhat higher, but do not indicate more than three stories, although there was probably another. The *vigas* of the second floor project through the wall for a distance of about 5 feet along its whole northern face the same as in the Pueblo Hungo Pavie. There are two *estufas;* one, near the east end of the wing which is 27 feet in diameter, was three stories in height. The floor beams are removed, but the remains show this plainly. The interior is nearly filled up, but it was originally over 25 feet in depth. The ruins of the other *estufa* are insignificant compared with this, and was probably of but one low room. Facing the centre of the court are remains of what were three circular rooms. At the end of the wings, outside of the building, are faint outlines of other circular apartments or enclosures, shown by dotted lines on the plan. In the central portion of the ruin, between the two wings, some rooms have been preserved entire. I crawled down into one of these through a small hole in the covering, and found its walls to consist of delicate masonry, thinly plastered and whitewashed. The ceiling was formed in the usual manner, fine willow brush supporting the earthen floor above instead of the lath like-sticks or thin boards that were used in the exceptional cases noted. The arroyo is undermining the soil close to the southwest corner of the pueblo, and has already exposed some old lines of masonry, which on the surface do not give any indications whatever of their existence. About 200 yards up the arroyo are the ruins of a small stone building similar to the ones which appear in connection with some of the preceding ruins. Its upper surface is mound-like, showing only faint traces of masonry, but the arroyo has undermined one corner, exposing well-laid walls extending down 5 or 6 feet below the general level of the valley. The arroyo is here 16 feet deep, but there is an older channel cutting in nearer the large ruin, of only about one-half this depth. It is in this that most of the exposed walls are shown. Below the remains of these walls, and extending out into the main arroyo to a depth of 14 feet below the surface, is an undulating stratum of broken pottery, flint-chippings, and small bones firmly embedded in a coarse gravelly deposit. I traced this stratum for several rods along the smooth perpendicular face of the wash, where it was very clearly defined, and picked out many pieces of excellently painted shreds of pottery. At the lowest point of this stratum, and where it had been undermined by the waters which sometimes flow in this arroyo, a human skull was exposed, so firmly embedded in the dense, rock-like

earth that considerable force was necessary to detach it; some smaller bones and numerous fragments of pottery were scattered about in the soil near by; it was in an inverted position, the crown half buried in the hard earth, a soft stratum above having washed out to a few inches greater depth, thus leaving it standing, as above described, on a little bench. The thin stratum of pottery could be traced also on the opposite bank of the arroyo and thence along its walls to the small ruin already described. This deposit represents the ancient surface of the grounds about the pueblo, and was probaby the sloping bank of the stream, which during the occupancy of this pueblo may have been a considerable river. Since the desertion of this region the old bed has become filled to the depth of at least 14 feet, and through this the arroyo has made its present channel. A system of thorough excavation would undoubtedly reveal many interesting things, and is probably the only method by which anything satisfactory will ever be learned of the industrious people who once filled this narrow valley.

PUEBLOS NOS. 8 AND 9.

At distances of a half mile and one mile respectively, are the ruins of two comparatively small buildings, built close up under the northern walls of the cañon. The first of these, which I have called Pueblo No. 8 in the plan, was originally a perfect parallelogram, 135 by 100 feet dimensions, without any adjoining buildings, walls, or court. From the fact that the outer walls are low and much ruined and that the highest walls are all nearest the centre, it would seem that it was originally terraced pyramidally like the great houses of Taos. The *estufas*, three in number, are nearly in a line through the centre. The two end ones are quite high and must originally have been at least two stories in height. It is possible, however, that their elevation is due to the fact that they are built upon large rocks which are entirely concealed by the fallen walls. The central *estufa* is low compared with the others and with the walls standing around it. These *estufas* are from 18 to 22 feet in diameter, with their circular walls 5 to 6 feet high and with unknown depth of *debris* in the bottom. The walls near the northeast corner and along the north side generally are standing three stories in height, or from 20 to 25 feet, with rough *debris* to indicate another story. The front is much more ruinous. The masonry throughout the building is of square blocks of sandstone about 8 by 5 by 3 inches, dressed and ground down both before and after they are laid in the walls, a clay mortar being used plentifully between them. The door-ways or windows, whichever they may be called, are quite uniformly 27 by 42 inches in size, and the walls in which they occur from 18 to 24 inches in thickness. The masonry about some of these door-ways is ground down so smoothly, apparently by grinding, that if a carpenter's two-foot square was applied to their angles it would prove them to be as exact as in the ordinary brick-work of the present time. There is no appearance of the minute mosaic-like stucco-work so noticeable in the other ruins. But little wood-work now remains, what there is consisting almost entirely of lintels of small sticks of wood above the windows.

The next ruin, which we have called No. 9, is still smaller and hardly deserves to be called a pueblo. Like the last it is a solid parallelogram, but is only 63 by 78 feet in dimensions. The interior is mostly occupied by two comparatively large circular apartments, only one of which has its interior wall in good order. The exterior of the ruin, along the front and left-hand side, consists of three or four stories of small rooms,



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none of which are larger than 5 by 8 feet inside. The walls now standing are about 28 feet high; those about the right-hand portion are entirely ruinous and it is difficult to make out the original design. Some little wood-work remains—a few *vigas* and some lintels over the windows.

PUEBLO PEÑASCA BLANCA.

Two miles farther down the cañon from the last-described ruin, and occupying the summit of a promontory-like point around which the Chaco swings in a sharp elbow, are the ruins of the Pueblo Peñasca Blanca. Next to the Pueblo Bonito this is the largest in exterior dimensions of all the ruins. With the exception of the Pueblo Pintado it is the only one on the south side of the cañon, and the only one, with another exception, built above the bottom of the cañon. It is also unlike all the others in its ground plan, being an almost perfect ellipse. Its greater diameter is north-northeast and south-southeast. The western half of the ellipse is occupied by a massive structure, five tiers of rooms deep, and the other half by a single continuous row of small houses, serving as a wall to enclose the court. The interior dimensions of this court are 346 by 269 feet; add to this the depth of the buildings surrounding it and we have a total exterior diameter of 499 by 363 feet with a circuit of 1,200 feet. The greater portion of the walls is so ruinous that but few of them are in place above the first or lower story, where they are in places to full height of the second story. The greatest height, however, is maintained in the second tier of rooms from the outside. The entire outside wall is thrown down, but the end and dividing walls are yet in a fair state of preservation, enabling us to measure from them with some accuracy. The great height of the *débris* would indicate at least four stories in the outside tier. Like the Pueblo Bonito, some portions were built in a very much better manner than others; greater care seems to have been taken with the more exposed walls, while many of the interior ones were built of rough stones covered with adobe plaster. The two end walls are better preserved than any other portion, and in them is a beautiful example of the horizontal alternations of thick and thin plates of stone. There are seven *estufas*, all situated near each other in the northern half of the inner circumference of the west side of the ellipse. Five of these are in a solid row, and of the two other larger ones, one is set back within the body of the building, and the other outside but adjoining it. The masonry of the interior surfaces is in good order, but does not show that they were more than the ordinary one-story apartments built above the surface of the court. In the northern angle of the ruin a break in the outside walls enabled me to crawl into one of the end rooms of the second tier. The only noticeable feature in the rooms thus exposed was the employment of thin boards in the construction of the ceiling, resembling in every detail those described by Surgeon Hammond in connection with the Pueblo Bonito; all the larger beams had their ends cut off perfectly smooth and at right angles to their length. In the centre of the ruin, back of the two largest *estufas*, are more entire rooms. Two of these, to which I gained access by a small hole broken through the wall near the ceiling, were each about 10 by 15 feet in dimensions and 7 feet in elevation. One was half filled with rubbish and the walls and ceiling black with soot and smoke. Crawling through a small door-way into the next room, I found a marked contrast to the first in the smooth whitewashed walls, but little stained. The ceiling of both rooms was constructed in the usual manner, a thick matting of willow brush coming in contact with the earthen floor above instead of the

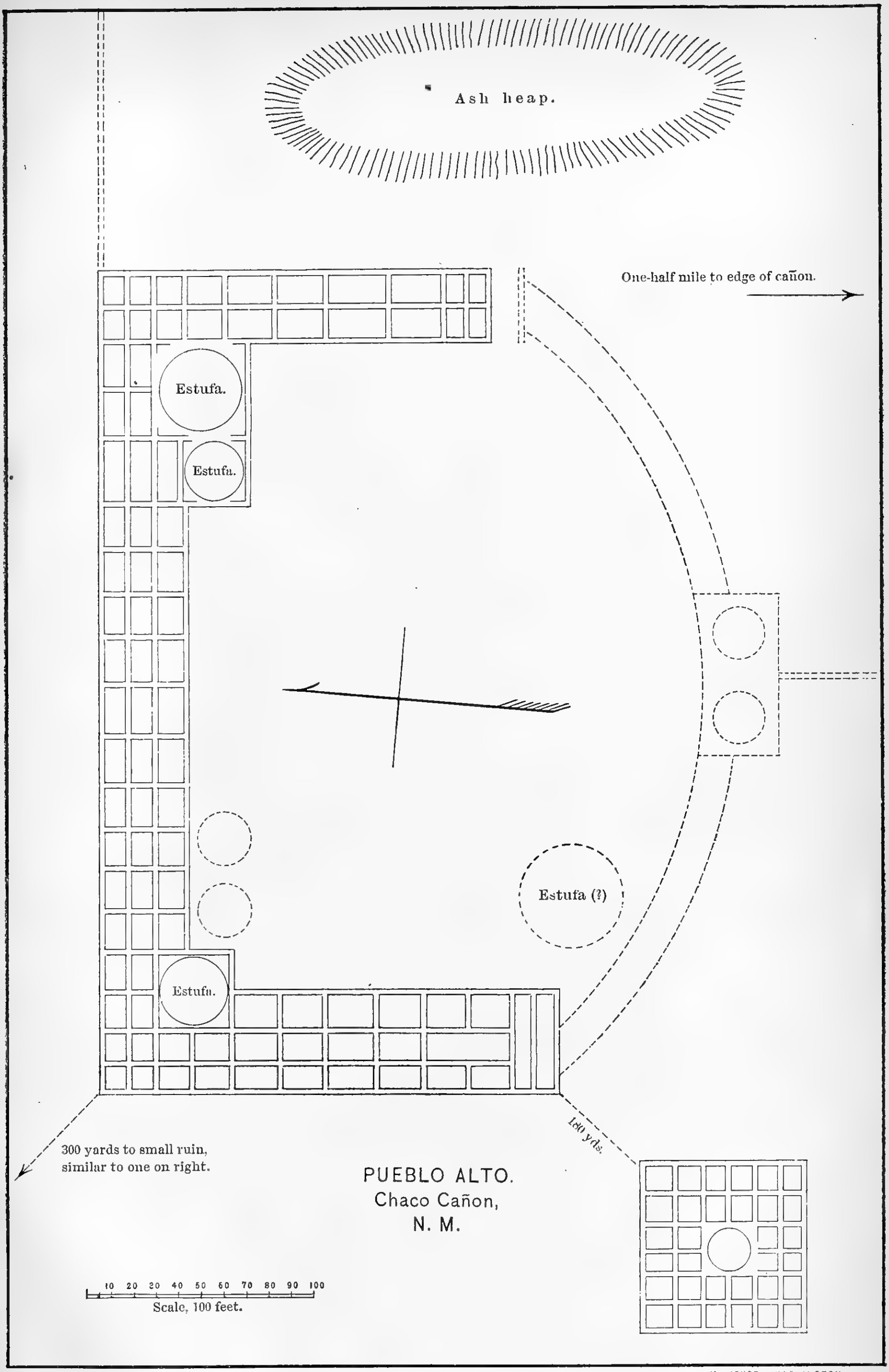
small boards. Upon the floor and a little to the right of the centre as we enter the room is a raised enclosure of whitewashed adobe, about 2 by 3 feet in dimensions and 8 or 10 inches above the floor. Inside it is at least 2 feet deep, but was filled nearly full with dust and dirt and the excrement of small animals. I scratched around in the mass to the bottom without finding anything of interest. In point of size, the rooms of this ruin will average larger than in most of the others; the twenty-eight rooms as they appear on the outer circumference average 20 feet in length from wall to wall inside. The smallest, which are only 10 feet wide, are at the two ends. The width of the rooms of each tier appears to have been constant throughout the length of the whole ruin. The dimensions given in these drawings are, in nearly every case, of those apartments which constitute the second story, as it is in those that there is the least obscuration of the walls.

In most of the ruins the first floor is almost entirely filled up with *débris;* but when the walls can be followed they show that this floor is generally divided into much smaller apartments, two or three occurring sometimes in place of each one above them. The eastern half of the ellipse, as above said, consists of a single continuous line of small apartments, with a uniform width of 13 feet inside and an average length of 20 feet. By a curious coincidence the same number of rooms are in this row as in the outer tier of the main building. The walls of the central portion, for a distance of about 200 feet, are in fair preservation, standing in places 6 to 8 feet in height, the dividing walls showing apertures leading from one room to another. They are built of stones uniform in size, averaging 6 by 9 by 3½ inches; mortar was used between the stones instead of the small plates of stone. At both ends, for a distance of some 200 feet from the point of juncture with the main building, the walls are entirely levelled, but enough remains to show the dimensions of each apartment. Twenty yards from the south end of the main building are the ruins of a great circular room 50 feet in diameter, with some portions of its interior wall in such preservation that its character is readily discernible. No masonry appears in connection with the exterior of the great mound, of which the cylindrical wall is the centre. At the north end there is another circular room of about 25 feet diameter, but this is surrounded by other rectangular apartments, and also by walls that probably terraced up the sloping surface.

PUEBLO ALTO AND STONE STAIRWAYS.

During the three days while engaged in the examination of the ruins from the Pueblo Una Vida to Peñasca Blanca, we made our camp in the bottom of the arroyo, about 250 yards below the Pueblo Del Arroyo, where we had found a few shallow pools of a thick, pasty water, the only remains of some recent shower. There was also considerable new grass just springing up among the willows and young cottonwoods, which extended half a mile above and below us, that was much relished by our half-starved mules, besides which the perpendicular sides of the arroyo served excellently as a corrall to restrain their wanderings. From this point we extended our trips up and down the cañon, returning to it each night, as affording the only water in the whole neighborhood.

While engaged about the ruin last described, I accidentally discovered with my field-glasses some ruined walls upon the summit of the bluff and apparently about half a mile back of either the Pueblo Bonito or Chettro Kettle. There was so little visible that I could not locate it much nearer. Having a couple of hours to spare before sunset one evening, I set about



M. JOYCE, WASHINGTON.

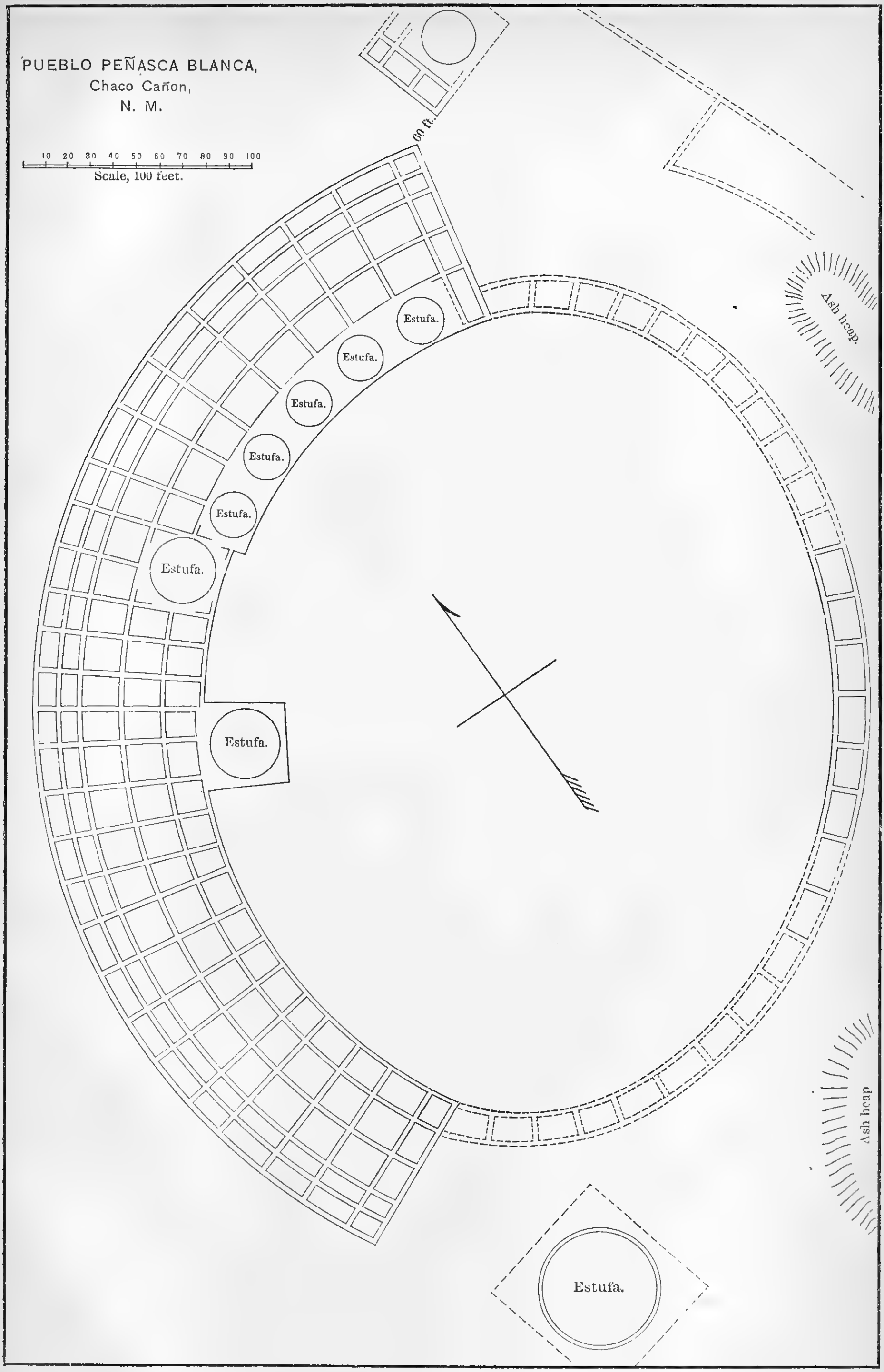
discovering a way up the bluff. Scanning the walls closely I saw where there had formerly been means provided for reaching the summit through some of the great crevices which run up to the top, but they now were inaccessible. Back of the Pueblo Chettro Kettle is an alcove with perpendicular walls about one-third mile in depth and 300 yards wide across its mouth. At the far end of this are the ruins of some old structure which had been built upon a low slope of talus, and evidently served as an approach up the bluff. Continuing around the alcove to its mouth opposite where I entered, I saw some steps and hand-holds cut into the rock that seemed to offer the opportunity I was seeking; climbing up a short distance over a slope of fallen rocks I found in the sides of the crevice an irregular series of stair-like steps hewn into the hard sandstone, each step about 30 inches long and 6 inches deep, the two cut surfaces at right angles to each other. Upon each side of these steps, in the steepest part of the ascent, are hand-holds so hewn out as to allow the hand to grasp them like the rounds of a ladder; in the other places they are sunken cup-like cavities, just large enough to admit the fingers. Easily gaining the summit, I walked back over the bluffs, ascending by terraces some 200 or 300 feet above the bottom of the cañon, and then turning around the head of the alcove, my attention was drawn to the stairway, shown in the accompanying drawing [plate LXII], hewn in the smooth and almost vertical face of a bluff, parallel with, and but a short distance back of that which forms the alcove. There are 28 or 30 steps of about the same size as those already mentioned, accompanied with the hand-holds on both sides. At its foot was probably a water-pocket to which it led, but immediately above there are no indications of any ruins whatever.

Interesting ruins, however, crop out in such unexpected places that something of the kind may be hidden away in the alcoves and ravines which penetrate the bluffs on all sides. From this point it was about half a mile over the sandy sage-covered plateau to the ruins I had seen from Pueblo Peñasca Blanca. They are situated so as to command the entire horizon. Away to the north stretches the great basin of the Rio San Juan; the summits of the La Plata Mountains glimmering faintly in the distance. The Sierra Tunecha stretches across the entire western horizon, while to the south above the elevated table lands appear the snow-covered summits of the Sierra San Mateo. In the east the summits only of the Jemez Mountains are in view, the frosted crown of Pelado shining above them all. This ruin is thus nearly midway and above all the others—dominating them so far as its position is concerned. I endeavored to obtain some information from Hosta as to its name among the Navajos or Pueblos. At first he professed entire ignorance of its existence, and said that none of his people or any of the Navajos knew anything of it. A day or two afterwards, however, while on the way home, he modified this statement by saying that there was a tradition among his people, of one pueblo among the others that was above them all, not only in position but in strength and influence, and was called El Capitan or El Jugador. He explains the latter name by saying that among his people the gambler was regarded as a type of a superior people. Whether or not this explanation was gotten up for the occasion, to explain something he knew nothing of, and yet did not wish to confess his ignorance, a manner in which most of these traditions are gotten up, it is impossible for me to determine; but as a compromise I have called the ruin Pueblo Alto. Referring to the plan in plate LX, we see that it is in the usual rectangular form, the open court facing south and enclosed by a low semicircular wall. The northern wall is 360 feet long and the

two wings 200 and 170 feet respectively. The east wing is but two tiers of rooms deep, while the other wing and the central portions are three tiers in depth. The rooms are large, many of them upwards of 20 feet in length, and from 8 to 12 feet in breadth. The masonry is of a fair order, but little inferior to the best of the others; but the whole ruin bears every indication of extreme age, and I have no hesitancy in pronouncing it the oldest of all. The walls are almost entirely destroyed, there being but little remaining above the first story. The *estufas*, three in number, one of which is 36 feet in diameter, are placed in the angles of the buildings. The inner walls of these rooms are in much better preservation than the rest of the ruin. In the court are other indications of other circular apartments in so ruinous a state as to be barely discernible, one of which is 45 feet in diameter. The ruins of the wall enclosing the court show it to have been of stone, and to have consisted of two parallel walls, and probably to have been subdivided into apartments, as in some of the others. Midway in this wall, and opposite the centre of the court, are the remains of what were evidently two circular apartments enclosed by rectangular walls measuring 40 by 70 feet, all in about the same state of ruin as the wall. At the east side of the court this wall does not join into the wing; a passage-way of some 12 feet width being left, just outside of which is an immense rubbish-heap, the cubic contents of which are approximately 25,000 yards.

From the northeast corner of the ruin, a wall extends 150 yards east and then turns south and runs about 200 yards to the edge of a bluff; a similar line runs parallel with it from the centre of the court to the edge of the same bluff, thus enclosing a space of about five acres, near the centre of which is the rubbish-heap. One hundred and eighty yards to the southeast are the ruins of a small, square building in a better state of preservation than the larger ruin. It is 75 feet square, divided into six equal apartments on each side, thus making 36 rooms in all, four of which, however, make room for an *estufa*. This was probably at least three stories in height, for the walls are now standing to the top of the second story. The masonry resembles that of the little pueblo numbered 9. About 300 yards to the northwest are the ruins of a similar building which is in a much more ruinous condition.

On the morning of our departure from this interesting region I rode from our camp to the foot of the bluff, about 200 yards below Pueblo Bonito, to examine some indications of human handiwork which appeared in a crevice, and which I had not theretofore noticed. Behind an immense bowlder which concealed the lower part I found a stairway built into a narrow opening running up to the top of the bluff; some of the steps were hewn in the manner already described, but there were others formed by sticks of cedar placed side by side wedged firmly in the crevice. Portions had decayed and fallen out, but enough remained to enable us to ascend. When once upon the summit we had a splendid bird's-eye view of the Pueblo Bonito, it being almost vertically beneath us, and were thus able to make out clearly at a single glance its irregular and complex outlines. The most important result, however, of this last discovery was the finding of a series of water-pockets in a deep crevice in the bare, rocky surface of the summit. They were so hidden from casual observation that one might pass within a very few yards of them without suspecting their presence. In these were thousands of gallons of clear, cool, sweet water, a thing we had not seen for many days, and what vexed us the most, it was discovered too late to be of any more use than for a single draught of the delicious fluid. They are deep pot-holes so situated as to protect the contents almost entirely



M. JOYCE, WASHINGTON.

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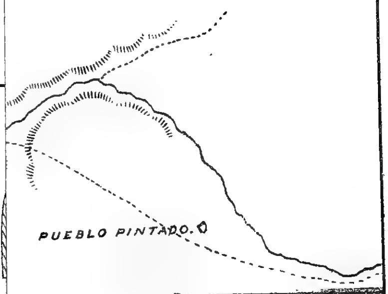

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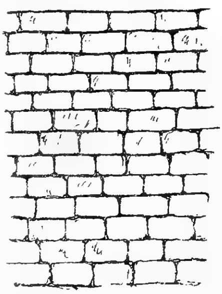

SONRY.

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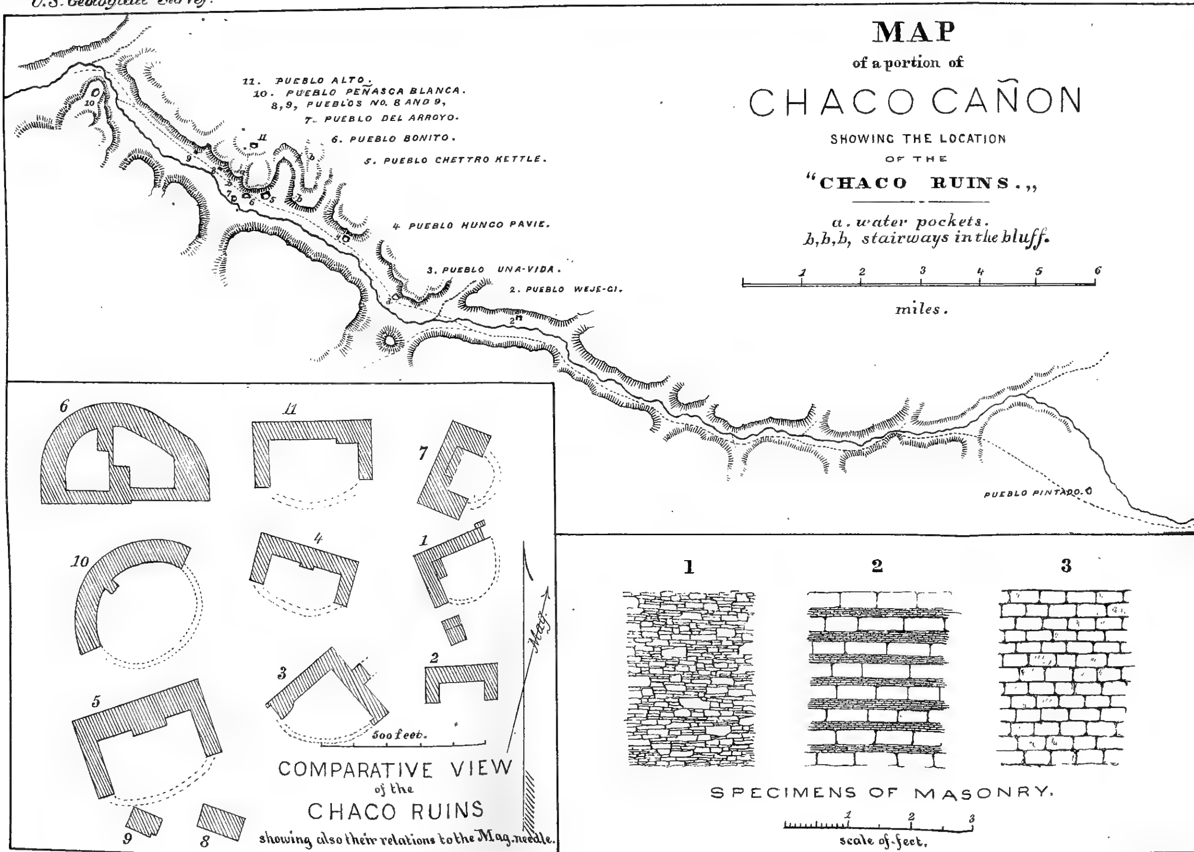
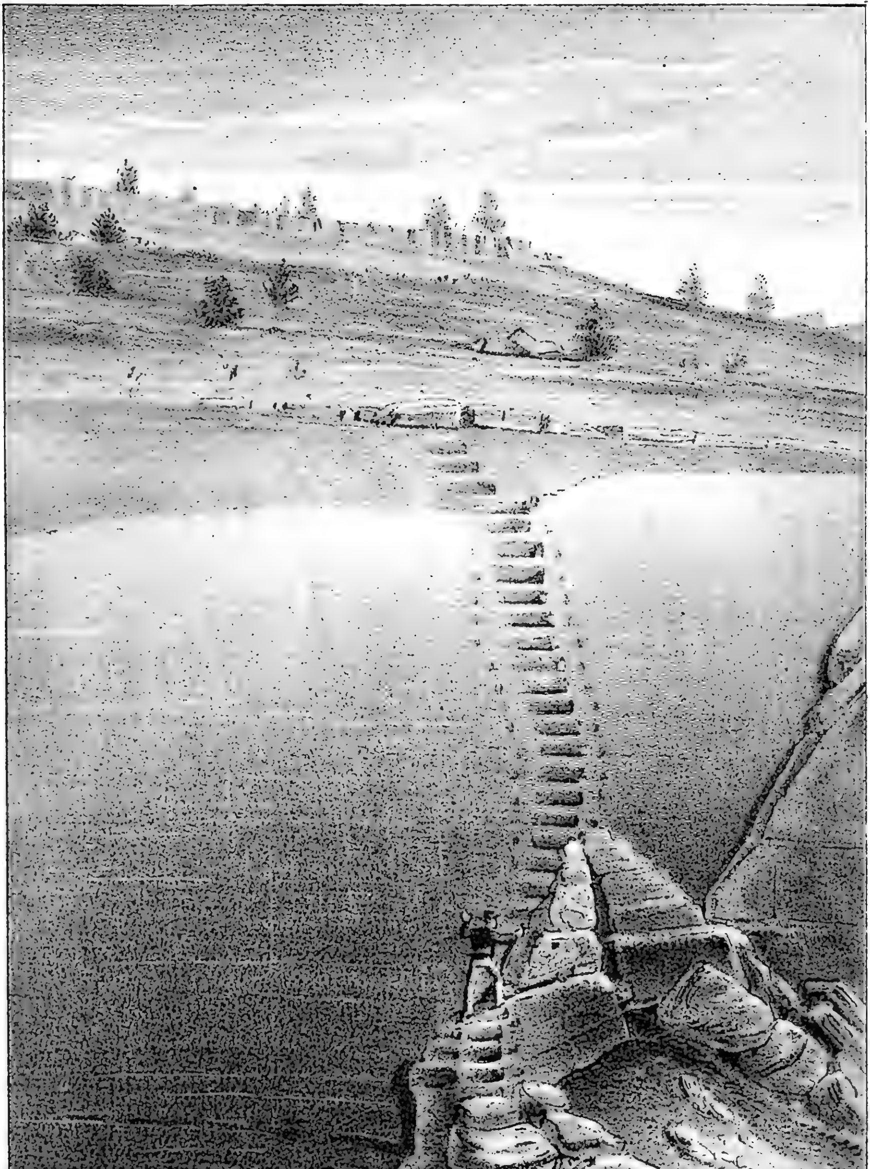


AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)



Thos Sinclair & Son. lith, Phila.

ANCIENT STAIRWAY

from the sun's rays, and the bare rocky surface all about them is so denuded of all soil, that the water is hardly tainted with the least impurity. A short distance below these pockets, and near the verge of the bluff, there had evidently been other and larger reservoirs of the same nature. The Pueblo Alto is directly back of this point less than half a mile, and it was from here that the people probably obtained much of their water.

POTTERY.

In the accompanying plates I have grouped a few of the most interesting examples of ancient and modern pottery, from the regions covered by our investigations. The ancient ware, as shown in the two first plates, represents some of the most striking examples of the taste and skill in ceramic decoration of the unknown potters. All who have ever visited the region of the ancient ruins, which covers all of New Mexico and Arizona, and portions of adjacent territory, have been impressed with the vast quantities of shattered pottery scattered over the whole land, sometimes where not even a ruin now remains, its more enduring nature enabling it to long outlive all other examples of the handiwork of the makers.

PLATE LXIV.

Fragments of painted ware, mostly of bowls and mugs, and, with but one exception, from the south side of the San Juan River. The material is generally dark gray, sometimes nearly white where the heat has been greatest, and is hard and firm, giving a clear ringing sound when struck. The paste shows a large percentage of a gritty substance resembling crushed fragments of burnt clay. The surface, however, is generally quite smooth, with a glossy appearance in some instances, much resembling a regular glaze. Upon this the black design lies without any perceptible wearing away, although these specimens have been exposed to all the disintegrating influences of soil and climate for centuries.

The pieces marked *a* and *b* are fragments of mugs, about 4 inches diameter and from 4 to 5 inches high, sometimes with handles, very much like an ordinary beer-mug of the present time. All the other pieces, with the exception of *c* (see also Plate XLV, Fig. 8), are from bowls, varying from 13 inches diameter to mere cups of only 4 or 5 inches diameter. *d* is a fragment from the Chaco Cañon. See Plate XLV, Figs. 1, 2, 3, and 4, for further details of this kind of pottery.

PLATE LXV.

Ancient Pottery. Nos. 1 and 3 are dippers with handles broken off; of a coarse, gray ware; from about the ruins of Montezuma Cañon; the first being found upon the plateau at its extreme head. No. 2 is a bowl that was found buried quite deeply near the ruins in Montezuma Cañon, described in page 428. Nos. 4 and 6 are pitchers from a grave on the banks of the San Juan River, near the mouth of the Mancos. The literal reproduction of the photographic process by which these plates are produced renders any further description unnecessary. No. 5 is a small jug, minus its handle, that was found buried among the ruins of the great Cave Town on the De Chelly (see page 421). It is as symmetrical in its outline as if turned upon a wheel, and the design is traced upon it with the most exact precision.

PLATE LXVI.

Pottery from the Moqui Pueblos. Nos. 1, 2, and 3 are spoons or ladles from Gualpi, decorated in black and red upon a yellowish-white surface. No. 4 is a double jug with an interior connection, found in Tégua, but supposed, however, to have come from Zuñi. No. 6 is a gourd-like jug, from Gualpi. No. 5 is a dipper, in imitation of a gourd, from Sechumevay. The handle is hollow, and is used in lieu of a funnel; after filling the bowl with water it is emptied through this handle into the narrow necks of the water-jars (see Fig. 2, Plate LXIX).

PLATE LXVII.

Basket work, and wooden images, or idols from the Moqui villages of Gualpi and Sechumevay. The conventionalized human face and figure which appears on the basket, occurs frequently in other forms in the decorative art of the Moquis.

PLATE LXVIII.

Zuñian Pottery. The art of molding earthen vessels in the shape of owls, ducks, and other animal forms familiar to them, seems to be confined almost exclusively to the Indians in the Pueblo of Zuñi.

PLATE LXIX.

Zuñian Pottery. Nos. 1, 3, 4, and 6 are in imitation of various domestic fowls. No. 2 is a miniature model, decorated, of the kind of water-jar in use among the Moquis. They are in the form of a sphere, with a capacity of about six gallons, flattened slightly on one side, with a narrow bottle-like mouth. On either side are two small rings or handles, through which is passed a small shawl or like piece of cloth, long enough to pass over the forehead and to suspend the jar against the back just below the shoulders. This mode of carrying water is rendered necessary by the precipitous nature of the pathways that lead to their springs. All the other Pueblo Indians carry their water in large, wide-mouthed jars, upon their heads. No. 5 is a common form of pottery among the Zuñians, both with and without handles.

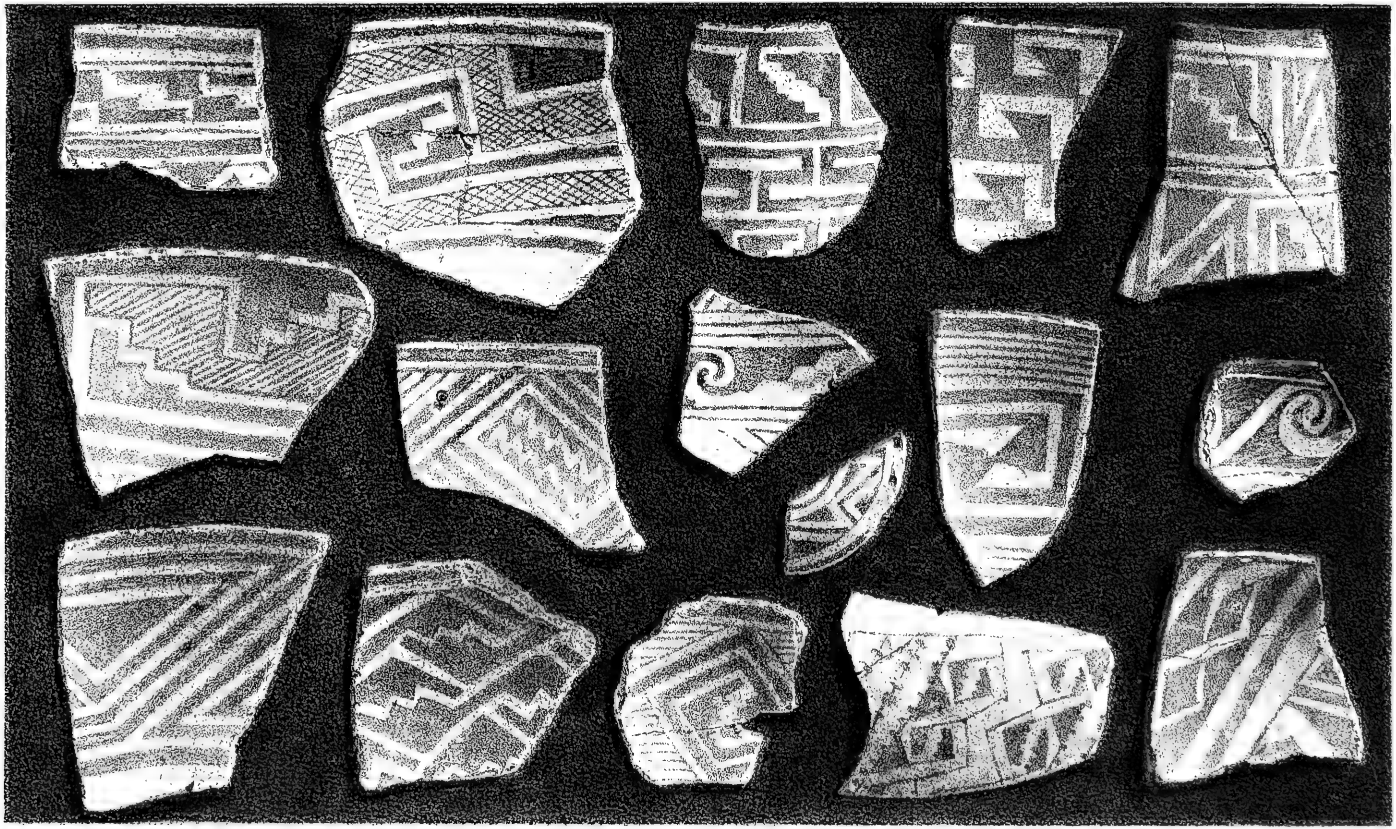
PLATE LXX.

Zuñian Pottery, representing an owl, an eagle, and a duck. The pieces shown in this and the preceding plate were loaned for the purpose of illustration, by Dr. J. V. Lauderdale, post surgeon at Fort Wingate, who found them at Zuñi.

PLATE LXXI.

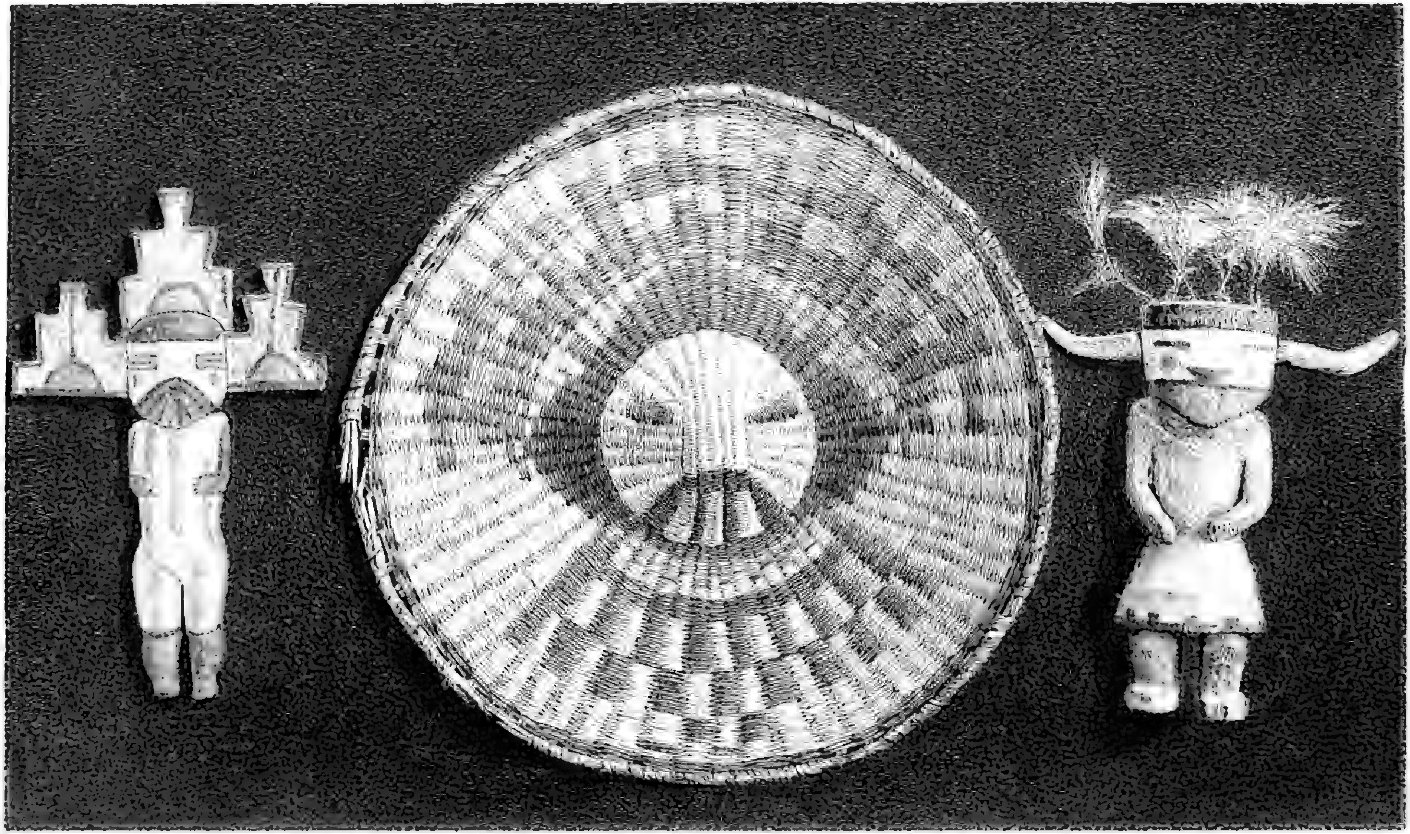
The central figure is a small *olla*, or water-vessel, such as are in use among the Pueblo Indians of New Mexico for carrying water upon their heads. The under side of the jar has a concavity which fits the convexity of the head. Small pads or cushions are also made for the same end. The two bowls are of Moqui manufacture, from Tégua. Moqui pottery is generally inferior to that of the other pueblos, being more porous, and lacking that compactness and ringing quality that is noticeable in the ancient ware, and in that which is made in Laguna and some of the other pueblos. In decorative ability, however, they are not at all inferior to the others.

PLATE [illegible]XIV



ANCIENT POTTERY

MOQUI POTTERY



MOQUI BASKET AND IMAGES

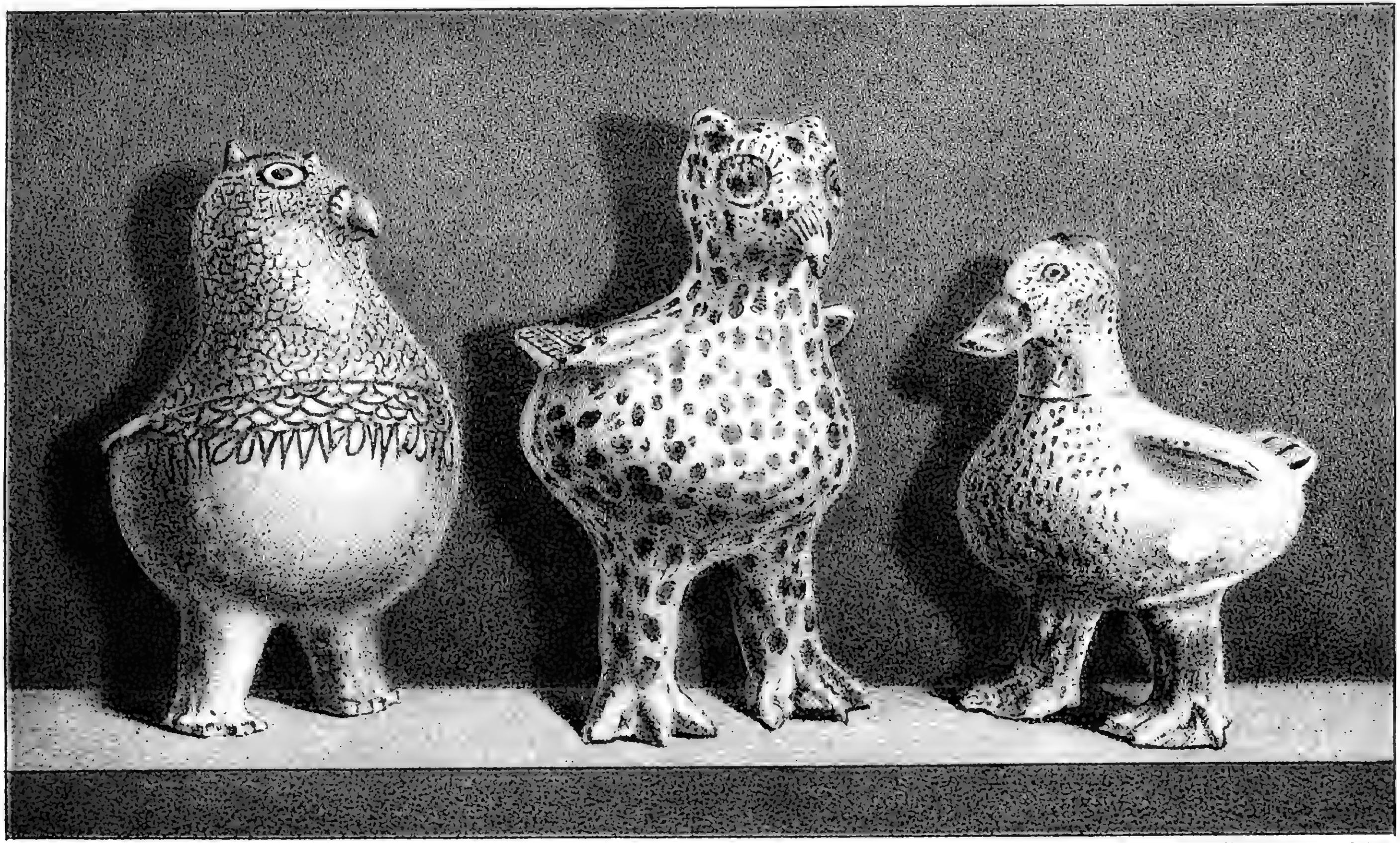
Thos Sinclair & Son, lith, Phila.

ZUNIAN POTTERY

PLATE LXIX

Thos Sinclair & Son, lith. Phila

ZUNIAN POTTERY

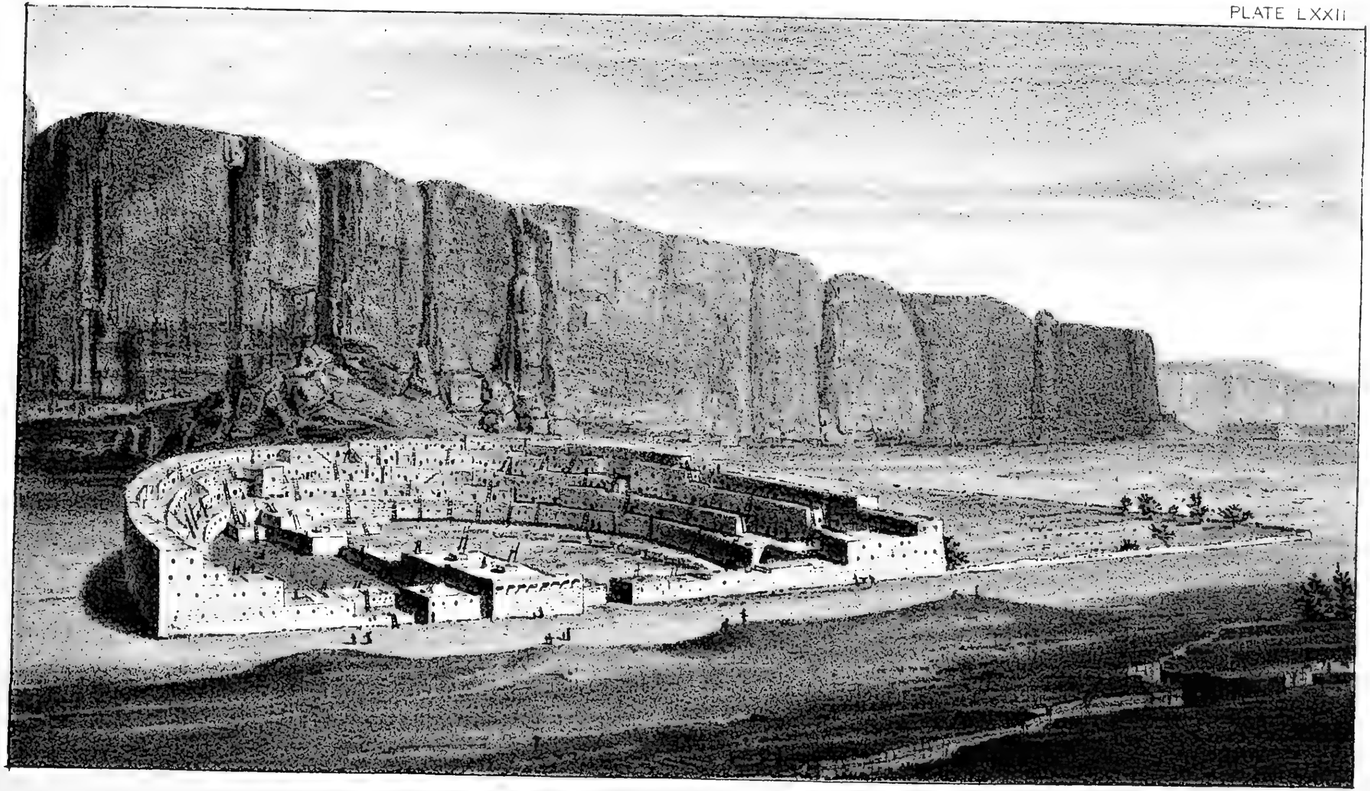


Thos Sinclair & Son, Lith

ZUNIAN POTTERY

MOQUI POTTERY.

PLATE LXXII



T. Sinclair & Son, lith. Phila

PUEBLO BONITO.
CHACO, CANON NEW MEXICO

REPORT OF W. J. HOFFMAN, M. D.

LETTER OF TRANSMITTAL.

UNITED STATES GEOLOGICAL AND GEOGRAPHICAL
SURVEY OF THE TERRITORIES,
Washington, D. C., December 31, 1877.

SIR: I have the honor to transmit herewith my report of observations upon a cliff-dweller's cranium, found in Chaco Cañon, New Mexico, by Mr. W. H. Jackson, at a depth of 14 feet beneath the surface, lying upon a stratum of broken pottery. The deposit in this cañon consists of alluvial drift, in which are several arroyos from 6 to 16 feet deep, by the erosion of which the lower stratum was brought to view.

Very respectfully, your obedient servant,

W. J. HOFFMAN, M. D.

Dr. F. V. HAYDEN,
United States Geologist in charge.

REPORT ON THE CHACO CRANIUM.

By W. J. Hoffman, M. D.

The discovery of a skull in Chaco Cañon (Northwestern New Mexico), belonging to the race which we recognize as the cliff-dwellers or ancient Pueblos, is one of considerable value and interest. Large ruins in excellent state of preservation occur in this valley, on as gigantic a scale as in any known locality. Human remains, in this region, had escaped attention until last season, when Mr. W. H. Jackson of this Survey, instituted greater search. Chaco Cañon, at the point under consideration, is about 500 yards broad, at the bottom of which is an alluvial deposit of sand and gravel, deposited here by the spring floods, at which time, and for a short period following, there is water. The valley contains numerous ruined pueblos, extending over a distance of about six miles from the two extreme buildings. Near the Pueblo del Arroyo, at which locality the skull was discovered, the wash or arroyo had cut a ditch 16 feet in depth. This wash followed the valley in a serpentine course, as all ditches or streams are apt to. At one angle of the bottom of the arroyo, where the water was guided to the left, it had partly undermined the embankment; here, at a depth of 14 feet below the surface, and two feet above the bed of the ravine, is exposed to view a seam or stratum of broken pottery, about 1½ inches in depth. At this point the skull was found, which will be described farther on. Following this stratum drown stream (or nearly westward) it gradually ascends until it comes to within a distance of 6 feet of the surface. A short distance above this appear the remains of an ancient foundation or stone wall, of former ruins. This terminates within a short distance of the surface. Other similar walls appear in various places along the arroyo, indicating that there had been a former occupation at a more remote period, than the time of construction and occupation of the more recent ruins, which are literally unknown. Over the present surface, which completely hides these ancient monuments, are scattered the ruins, which are known as the pueblos. These and the cliff-dwellings are supposed to have been constructed and inhabited by the same people; the latter having been built on account of the annoyances and hostile incursions of neighboring tribes. These cliff-dwellings are on a grander scale and occupy more desirable locations than those which we find in the eastern interior of Arizona, which came under my personal observation. In the latter locality, buildings occupying a level surface are rare at this day. Ruins are abundant, consisting of thick stone walls, upon which subsequent adobe dwellings had been erected. As the cliff-dwellings predominate, there is reason to suppose that the region just mentioned formed the most southern border of the country occupied by the various families and communities composing this extinct race, and for that reason there was need of greater security against surprise from enemies. These ruins

are not numerous considering the amount of relics which we find, such as the fragments of pottery, flakes, and implements and weapons, and the population could not have been as great as is generally supposed, but on the contrary it is the result of a prolonged occupation of the soil. Mr. Jackson states that he does not believe the population of Chaco Cañon to have exceeded twenty-five hundred persons.

The fragments of pottery found in the stratum in this cañon appear, according to Mr. Jackson's observations, to have been covered with alluvial drift by repeated floods, as the layers from above dip westward and downward, resting unconformably upon the stratum of pottery. The sections and remains of stone walls are in good preservation, and do not appear to differ from those of the surface. The fragments of pottery examined show no traces of having been subjected to the action of water and gravel, but appear to have been covered with a layer of sand and gravel within a comparatively short period. A few pieces upon which the broken edges appear somewhat rounded and worn, are in no wise affected upon the glazed surfaces, but present such an appearance as is perceptible upon fragments which have been exposed upon the upper surface. The only material difference between the two varieties, *i. e.*, those from the covered layer and those from the surface and ruins, is that the former are harder and better baked, and have a clear ringing sound when lightly struck with a hard body, which is absent to some extent in the latter. The designs of ornamentation are similar in fundamental structure.

About the ruins in Arizona, the surface specimens are similar to those from Chaco Cañon, but among them we find numerous remains exhibiting more complex designs in ornamentation, and more frequently specimens which exhibit none at all, but merely indentations and cleanly cut lines done by means of a sharp pointed instrument, showing not only as high a state of cultivation as the enamelled ones, but also that they were made in less time, as if from fear of interruption.

CRANIUM.

Asymmetrical; apparently that of a female. The eruption of the last molars has not taken place. The whole of the cranial cavity is completely impacted with sand and gravel, which is now of the consistence of agglutinated sandstone, and any attempt at its removal would prove disastrous to the specimen. Since its discovery, the skull has received some injury in transportation, breaking off the superior maxillary bones, and as the faces of fracture are worn and rubbed, no facial angle can be obtained. It is rather brittle, of a grayish yellowish-brown color, and in some places of a chalky consistence. The outer tables are rather hard. The ethmoid line, zygomatic processes, and inferior maxillary are wanting. The termini of the zygomatic processes indicate them to have been thin and slender. A facial view presents a narrow forehead, widening upward and posteriorily, giving the greatest breadth across the bi-parietal region; orbits apparently oval; nose broad, considering the curvatures of the inferior portion of the nasal eminence and the superior anterior portion of the maxillary bone. Frontal eminences coalesce, and retain a central elevated ridge downward to the nasal eminence, which is rather broad and prominent. Superciliary ridges are very slight, containing a foramen and notch over the left orbit, and two foramina over the right.

The most striking peculiarity is the great flattening of the posterior portion of the skull, including the anterior portion of the occipital and

CRANIUM OF ANCIENT CLIFF DWELLER
FROM CANON CHACO, NEW MEXICO

the posterior superior portions of the parietal bones; the larger portion of the flattening being over the left portion of this region. The pressure appears to have been to some extent from the left side, and has directed considerable influence upon the anterior portions of the parietal bones, and the superior lateral portions of the os frontis. Taking into consideration the curvatures and convexities, such as would be produced by any attempts at flattening, as practiced by aboriginal races, I do not believe it to have been post mortem deformation, but, on the contrary, an example of a former custom. In the absence of a complete facial structure, some idea can be obtained by taking an angle of measurement of two lines, one crossing the flattened surface of the skull, the other drawn from the nasal eminence upward, over the forehead, which is pretty straight to that point between the frontal eminences. These lines intersect at an angle of 27°. The frontal bone, behind the external angular processes, forms a moderately deep groove, which intensifies materially as it continues downward over the sphenoid. This is more prominent upon the left side than upon the right. The tubercles of the zygomatic processes are prominent. The glenoid fossæ are unusually deep and well defined. The antero-posterior diameter of the foramen magnum is the greatest, this being due to the existence of a posterior notch, from the middle of which the crest takes a rather irregular course upward to the inferior curved lines, which are rather obscure. The crest is prominent, rather sharp, and well defined, upon either side of which the depressions for the insertion of the rectus posticus major and rectus posticus minor muscles, are deep and remarkably developed. The superior curved lines are deficient, and the surfaces for the insertion of the complexus muscles are irregular, and decidedly rough and corrugated.

The serration of the sagittal suture is rather coarse. The coronal suture as it recedes toward the occiput becomes more acutely developed, and contains several small Wormian bones. The lambdoidal suture is remarkable in serration and for the width which it occupies. Several Wormian bones of large size exist in the left portion; in the right they are not so large but more intricate in serration. The extreme length of the largest one, extending from the anterior angle of the occipital bone toward the left, measures 1.12 inches.

As there is some tendency to expansion of the mass of sand contained within the cranial cavity, the sutures have separated slightly. In making the following measurements, due allowance has been given for this, and the measurements, although only relative in several instances, are sufficiently accurate for all purposes.

	Inches.
Length	6.20
Biparietal diameter	5.58
Frontal diameter, greatest	4.75
Frontal diameter, least	3.50
Vertical*	5.13
Horizontal periphery	18.90

The measurements can only be given in part, as many of the protuberances have been removed in transportation. In fact, some of the cellular portions of the base of the skull are impacted with sand, a proof that decay occurred even while in the drift. The sand is dry, as it is in all cañons, in the regions where cliff-remains and pueblos are found, during the greater part of the year. Spring floods are of comparatively short duration, and what little water remains in the arroyos and pools soon evaporates or disappears in the porous alluvial sand. That the country

* Taken from the anterior margin of foramen magnum to the posterior termination of the first third of the coronal suture.

was agriculturally good, well watered and wooded, we have proof from a mere glimpse. Since the climatic change it is not fit to support life in the great majority of cases. This change has been attributed to geological causes. In this I do not fully agree. In Arizona are remains of arroyos about 40 feet above the present level of any streams, by which the agricultural regions were irrigated.

In tracing up these remains, we find them to have originated in valleys from 10 to 18 miles away, where there was an abundance of water at one time, as the pebbles and rounded bowlders show. These have long since dried up. In nearly every locality we find evidence of a time when water was abundant.

It is natural to suppose that a community, however large or small, must in time cut away the timber, both for building and as fuel. This thoughtless or negligent *deboscation* must eventually affect the soil and annual rain-fall. Aqueous precipitation decreases year by year, springs and streams begin to dry up and disappear, until there is not enough for ordinary consumption. These statements are made from direct observation of the physical features of the cliff-dwellers' country, and the results of cutting away forests and woods in other localities, and I suppose I will be borne out in my belief that the gradual depopulation of the country under discussion was due, indirectly, to their own ignorance or thoughtlessness, as much as it was to the influence of hostile neighbors. The latter they had in any number, if we can take into consideration the positions of their architectural remains, but when a country is getting poorer and poorer, and the outside annoyances are greater than a possession of the soil is worth defending, we can very readily understand what would be the final result.

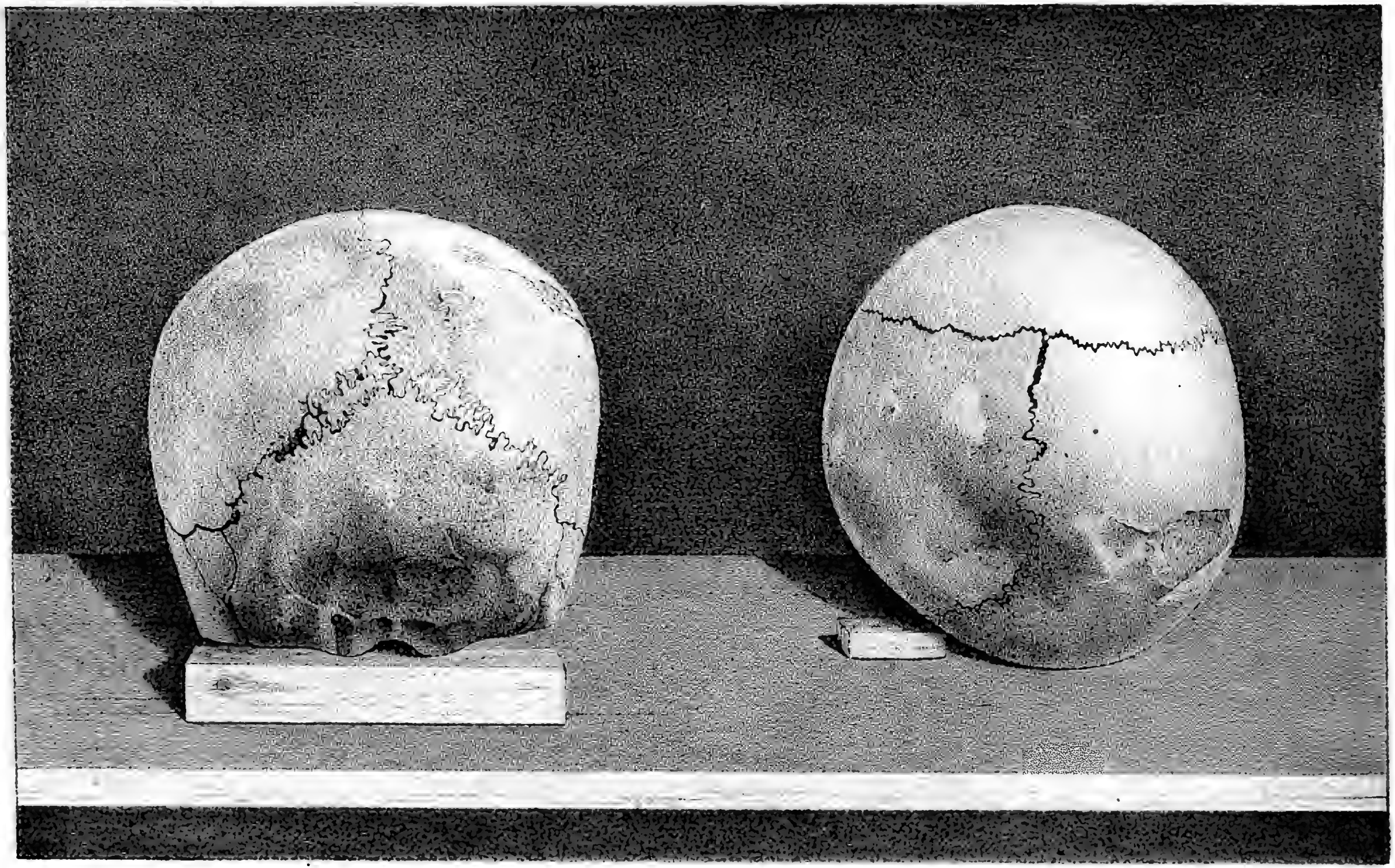
In connection with the skull there was one bone found, apparently belonging to the *Tetraonidæ*. The bone has not been further identified.

Dr. Bessels seems to think the present Pueblos are a remnant of the ancient race of Pueblos or Cliff-Dwellers.* He bases his hypotheses upon the similarity in architectural and ceramic remains. The crania which he describes in his report present occipital flattening, but not in so marked a degree as exists in the Chaco cranium. This head-flattening is practised by various tribes of aborigines in the Columbia River region, but south of that we lose all trace of it until we reach the northern portion of the country formerly included in the Mexican region. It has been supposed by various prominent ethnologists and old writers that there had been in remote times, a migration towards the regions in various directions northward from Mexico. In time a return is traced, some assuming Aztlan to have been the point of departure, while a large and long-continued influx of people came from a country or kingdom in the northeast. Language has left its imprint among various existing races, and we find great affinity between that of the Natchez, who formerly occupied the lower portion of the Mississippi Valley, and the Mayas. Greater radical affinity is observable among many of the tribes scattered southward through Mexico into Central America, and similar customs to a remarkable degree can be traced. The head-flattening is also found to have existed, to more or less extent, among some of the Peruvians, Caribs, Mexicans, and Natchez. In comparisons made with specimens at the Army Medical Museum, we can observe more or less similarity.

Dr. Morton† figures several crania, the measurements of which I give

*Bul. U. S. Geolog. and Geograph. Survey of the Territories, Vol. II, 1876, pp. 47–63, Pll. 23–29.

†Crania Americana, S. G. Morton, M. D., Philadelphia 1839.



Thos. Sinclair & Son, Lith.

CRANIUM OF ANCIENT CLIFF DWELLER

FROM CANON CHACO, NEW MEXICO.

to illustrate the general comparison. Occipital flattening is remarkably prominent, and I give the numbers in their order of nearest approach to the Chaco skull, as regards shape, bearing in mind that the latter is, to all appearance, that of a young female, and consequently somewhat smaller than the cranium of a male would measure.

The first is the skull of a Natchez, pll. 20, 21; the second and third of Pames (Mexican), pl. 17*a*, and Mexican, pl. 17; and the fourth a Mexican, pl. 18.

Race.	Length.	Parietal diameter.	Frontal diameter.	Vertical (height).	Horizontal periphery.	Total of length, breadth, and height.
1. Natchez	5. 9	6. 6	4. 6	5. 1	19. 6	17. 6
2. Pames (Mex.)	6. 6	5. 3	4. 3	5. 2	19.	17. 1
3. Mexican	6. 8	5. 5	4. 6	6.	19. 9	18. 3
4. Mexican	6. 4	5. 7	4. 5	5. 4	20. 2	17. 5
5. Chaco skull	6. 20	5. 58	*4. 75	5. 13	18. 90	16. 91

* Greatest diameter, as in the others.

The general measurements and results are closely related, and might be more so had we a skull of a mature adult, and of known sex. There appears to have been some relationship between the ancient Cliff-Dwellers and the modern Pueblos, and finally the Aztecs or Mexicans, at or before the time of the Spanish conquest. The general designs in ornamentation appear traceable in the Aztec pottery, and the ruins at Mitla, only in a higher state of cultivation. At the latter the designs have appeared upon the walls of the ruined temple and upon a grander scale. The Aztec traditions of a northwest origin are strongly in favor of such a hypothesis, beside numerous arguments which might be brought to bear upon the subject.

The accompanying sketches illustrate the appearance and outlines of the various positions of the cranium.

REPORT OF W. J. HOFFMAN, M. D.

LETTER OF TRANSMITTAL.

OFFICE OF UNITED STATES GEOLOGICAL AND
GEOGRAPHICAL SURVEY OF THE TERRITORIES,
Washington, D. C., December 31, 1877.

SIR: I have the honor to transmit herewith a report upon Ethnographic Observations upon several of the aboriginal tribes and sub-tribes inhabiting the western and southwestern portions of the United States.

Very respectfully, you obedient servant,

WALTER J. HOFFMAN, M. D.

Dr. F. V. HAYDEN,
United States Geologist in charge.

MISCELLANEOUS ETHNOGRAPHIC OBSERVATIONS ON INDIANS INHABITING NEVADA, CALIFORNIA, AND ARIZONA.

By W. J. Hoffman, M. D.

INTRODUCTION.

The materials and data for the accompanying remarks I collected chiefly in Nevada, California, and Arizona, while attached to the United States Geographical and Geological Survey west of the one hundredth meridian in 1871–'72, as surgeon and naturalist. Since then, valuable notes have been received, for which due credit has been given. Frequent allusions to the Dakotas are made merely for the purpose of illustrating corresponding or differing customs. Observations were made in the country of the latter during the years 1872–'73. The tribes visited in 1871, are located and named as follows:

1. Shoshonees, Pah-Utes, Nevada.
2. Pah-Utes, California.
3. Seviches, Hualpais, Mojaves, Apachè Mojaves, Apachè Coyotèro, Apachè Arivapah, Pimas, Maricopas, Yumas, Arizona.

The Shoshonees occupy the upper interior of Nevada, thence southward, between the regions inhabited by small bands of various subtribes of Pah-Utes, as far as Grapevine Springs in Armagosa Desert, northwest of Spring Mountain, about latitude 115° 40′ west, and latitude 37° north. Very little of the southern portion is fit for the Indians, for raising corn, melons, &c., and it is seldom any are found, excepting in small ravines or valleys along the mountain sides, where a few families may be found in temporary camps. The Pah-Utes are cut up into various bands, each under the direction of their chiefs, but entirely independent of one another unless when they unite in defence against a common foe. The Seviches and Hualpais are but semi-civilized and are not inclined to go to any regions occupied by the whites. They occupy the western and northwestern edges of the Colorado Plateau. Immediately south and southwest of the latter are the Apachè Mojaves, a semi-hostile wandering band. They are now drawing more toward Camp Verde as a centre.

Little need to be said of the wandering hordes of Apachès who roam over the interior and southeastern portions of Arizona. Their cruelty to prisoners is unequalled anywhere. They practise at times the most barbarous and inconceivable modes of torture upon their victims; and in this respect they are not unlike their former neighbors, the Mexicans.* The Mojaves and the Yumas are both located upon the Colorado River, the latter below the mouth of the Gila, and the former about 300 miles above. The Pimas, Maricopas, and several others are located at various points along the Gila River in the vicinity of ancient remains, a prominent ruin of which is known as "la Casa Grande." These have been described by various writers, and require no notice here.

* Bernal Diaz. &c., J. J. Lockhart, vol. ii, p. 89. London, 1844.

The different articles have been placed under different heads for the sake of convenience, a complete history being superfluous and unnecessary; such notes only being treated in detail as were considered of more importance and more frequently passed over by others who have visited the regions under consideration.

The following remarks have been classified and arranged under the following titles:

1. Dress, pastimes, &c.
2. Food.
3. Fire.
4. Utensils and weapons.
5. Medicine and incantations.
6. Disposition of the dead.
7. Stone circles and signals.
8. Pottery and pictographs.
9. Ruins.

1. Dress, pastimes, &c.

The clothing of the tribes need not be described in detail, as this has been frequently and ably done. The Apachès in Central Arizona, the Hualpais and the Seviches, prepare deer-skins by smoking with rotten cedar or juniper wood, after having been subjected to the usual mode of cleansing and preparation. The skins are generally of a yellowish-red to a reddish-brown color. The women are usually better clothed than the men, owing to a latent sense of modesty which has not and will perhaps never be thoroughly eradicated. The Mojave women use a very neat style of petticoat, made of strips of the inner bark of the cottonwood, tied about the waist and falling down to the knees or a short distance below, with a protrusion behind in the form of the modern bustle, upon which the children frequently sit astride when too young to run unassisted. The Apachè women carry their infants tied upon frames covered with thongs, similar to the Dakotas. The male population of nearly all tribes are known to devote a considerable time to games of chance and other pastimes.

The Mojaves are very fond of a simple game played by three or four, in which five small heaps of sand are formed, when the player hides a stick in one of the piles, singing during the time as an accompaniment. The rest of the players then guess at the pile containing the stick, staking various trinkets, money, or other articles upon the result. The Coyotèro Apachès manufacture very nice cards, about the size of an ordinary playing-card, from tanned horse-hide, upon which they draw various figures, lines, or characters in various colors, resembling to some extent the ruder styles of Mexican montè cards.

Lieutenant Whipple* in speaking of the Mojaves says, "Some of the young men selected a level spot, forty paces in length, for a play-ground, and amused themselves in their favorite sport with hoop and poles. The hoop is six inches in diameter, made of an elastic cord. The poles are straight and about fifteen feet in length. Rolling the hoop from one end of the course, two persons chase it half way, and at the same instant throw their poles. He who succeeds in piercing the hoop wins the game."

The Coyotèro Apachès play this game in nearly the same manner. A perfectly level piece of ground is selected, which is afterward retained

* Pac. R. R. Rep., vol. iii, 1856, p. 114.

for this game only. A distance of about 25 paces is marked off, having a width of about 4 feet. Two play the game, and the necessary materials required are a pole for each of the players, and a hoop made of a branch of tough wood nearly an inch thick, which is formed into a ring having a diameter of about 6 or 7 inches. This is sometimes wrapped with raw-hide or sinew. Then there are two cords running horizontally across the inner space, crossing two similar ones attached vertically, giving the middle the appearance of the cross-wires in an engineer's transit. The poles are each about 15 feet long, consisting of spliced pieces of cottonwood, about the general appearance, finally, of a good-sized fishing-rod, with the thin end slightly turned upward. When the players are ready, they take their positions at one end of the course, one of them placing his forefinger on the periphery of the hoop, and grasping the sides with his thumb and fingers. The hoop is rolled so as to reach the outer end of the course, and as it reaches half way the distance the players start abreast, pushing the poles on the ground before them. When they reach the middle of the course the poles are pushed ahead so as to try to penetrate the hoop, or any segment of it (caused by the cords), the game resulting upon previous agreements as to what was required in counting. This is repeated from the end where the first attempt terminated, and continued for hours. I have seen men lose blankets, horses, bows, and arrows, and in fact almost anything of which they were possessors. I do not recollect the name of this game; nor is this of as much importance as the existence of the game itself.

The Abbé Em Domenech* describes a game of this character as observed in the extreme western portion of the continent.

Catlin† gives a description of the *Tchung-kee* game as one of the amusements of the Mandans.‡ This was played with a stone ring 2 or 3 inches in diameter.

Adair§ describes the national game of the Cherokees under the name of *chungke*, and gives a detailed description.

Jones‖ says, "The great game upon which the Southern Indians staked both personal reputation and property was the *chungke game*." DuPratz,¶ Brackenridge,** Lewis and Clarke,†† Turner,‡‡ and Morgan§§ notice this game among different tribes. It has pretty generally disappeared, and, as far as I am able to learn, it is played to-day, with some slight modification, only by the Apachès. Since the manufacture of stone ornaments and implements generally has been discontinued owing to the encroachments of civilization, wood and other materials are substituted, saving thereby a vast amount of time and labor, of which aborigines are always ready to avail themselves if possible.

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* Seven Years' Residence in the Great Deserts of North America, vol. ii, p. 197. Lond., 1860.

† Illus. of the Manners, Customs, and Conditions of the N. American Indians, etc., 10th Ed., vol. I, p. 132, pl. 59. Lond., 1866.

‡ Prince Maximilian also noticed this among the Mandans and *Manetaries*. < Travels in the Interior of North America. London. 1843. p. 358.

§ Hist. of the Am. Indians, etc., p. 401 *et seq.* Lond., 1775.

‖ Antiq. of the Southern Indians, 1873, p. 96.

¶ History of Louisiana, 1720, p. 366.

** Views of Louisiana, pp. 255, 256.

†† Lewis and Clarke, (by Paul Allen), Philadelphia, 1814, vol. i, p. 143.

‡‡ Traits of Indian Character, vol. ii, 1836, p. 168.
[Extracted (in substance) from Halliday Jackson's "Civilization of the Indians."]

§§ Third An. Rep. of the Regents of the Univ. of N. Y., 1850, p. 81.

Bartram* observed this game among the Creeks, and calls it "chunky-yard."

The only dances which I had an opportunity of witnessing were among the Shoshonees and Coyotero Apachès. There is no peculiar feature in that of the former, their style of accompaniment being the same monotonous drumming and singing as witnessed among various other tribes *east* of the Rocky Mountains. The Apachè dance was the occasion of a gathering for the purpose of disposing of a quantity of "mezcal whisky." At this dance it was the custom for the Apachè maidens to go around and select their partners. When the festivities had been continued until toward midnight, the dance terminated at the appearance of four masked Indians entering the circle from the four cardinal points and taking a "hop-around." The liquor was then disposed of, when the crowd dispersed very boisterously. Subsequent transactions must be omitted, although they are of ethnographic value. I may here state that prostitution was formerly punished by cutting off the tip of the criminal's nose.† This applies only to the female, as the male was rather honored for the conquest.

Dr. Smart, United States Army, says that he saw women who had the cartilaginous portion of the nose cut off, and this was apparent only amongst those who had any pretensions to beauty.‡ Maidens are known by having some of the hair over the ears wrapped in brass wire in the form of coils. This peculiar custom was also practiced among various tribes southward as far as the Isthmus of Panama.

Marriage or the selection of a bride is rather an amusing custom when compared with similar usages in civilized life. Frequently one sees two parallel rows of stones along prominent foot-paths or trails, which indi-

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* Bartram's Travels in N. and S. Carolina, etc., Philadelphia, 1791; London, 2 vols., 1794; Paris, an. vii (2 vols).

The Cuchanos (Yumas) also played this game, known then as *mo-upp*; in Spanish, *redondo*. <Emory's Report U. S. Mexican Boundary Survey, vol. i, p. 111.

The Choctaws played the chunke game. It was called "running hard labor" by some of the traders. <History of Alabama, etc., A. J. Pickett, Charleston, vol. i, 1851, pp. 141, 143.

The Cherokees were also very fond of the chunke game. <A. J. Prickett, *ibidem*.

† In his allusion to this custom as practiced by the Comanches, Gregg says: "The husband seems to have complete power over the destinies of his wife and children. For adultery, his punishment is most usually to cut off the nose or ears, or both; and he may even take the life of his unfaithful wife with impunity. The squaw who has been mutilated for such a course is *ipso facto* divorced, and, it is said, for ever precluded from marrying again." <Commerce of the Prairies, etc., New York, 1844, vol. ii, pp. 308, 309.

"Las faltas conjugales no se castigan por la primara vez; pero á la segundo el marido corta la punta de la nariz a su infiel esposa, y la despida de su lado." <Revista Cientifica, vol. i, p. 57.

[Quoted from Bancroft's Native Races (author's copy), vol. i, 1874, p. 515.]

Mr. Gregg also states that "this custom prevails among the Creeks to the present day, and was anciently practiced by other southern nations. 'Among the Miamis', says Father Charlevoix, 'the husband has a right to cut off his wife's nose if she runs away from him.'" *Ibid.*, p. 308.

Bancroft says that in Itztepec (Mexico) "the guilty woman's husband cut off her ears and nose, thus branding her as infamous for life." <Nat. Races of the Pac. States, 1875, vol. ii, p. 466.

[Las Casas. Hist. Apologética, MS., cap. ccxiii; Mendieta *ubi sup.*]

"Among the Miztecs, when extenuating circumstances could be proved, the punishment of death was commuted to mutilation of ears, nose, and lips." <Bancroft's Nat. Races, etc., 1875, vol. ii, p. 466.

[Herrera, Hist. Gen., dec. iii, lib. iii, cap. xii.]

This practice appears also among the Indians inhabiting Florida. <Concise History of East and West Florida, Captain Romans, 1775, p. 98.

‡ Notes on the "Tonto" Apachès. <Smith. Rep. 1867, pp. 417–419.

cate that at a previous time some anxious lover frequented the locality to learn his fate.

When an Apachè Indian has made his selection from among the maidens of his tribe, he watches her most frequented trail, upon which she leaves camp for the purpose of gathering berries, grass-seed, or other food. She becomes aware of the intentions of the young warrior through the same means known to the sex "all the world over," and is prepared to accept or reject his proposal, which remains an unspoken one. For the furtherance of his object, the Indian visits a secluded spot through which the trail in question passes, places a row of stones on both sides of it for a distance of ten or fifteen paces. He then allows himself to be seen by the maiden before she leaves camp, and running ahead, hides himself in the immediate vicinity of the rows of stones. If she avoids them by passing to the outside it is a refusal; but should she continue on her trail, and pass between the two rows, he immediately rushes out, catches her, and * * * takes her triumphantly to camp.

If a white man or a Mexican wishes to obtain a wife through the regular channel, he is required to deposit an amount of money or horses and blankets with the girl's father for the period of one year. If at the end of that time the lover should be of the same opinion, he takes his bride and receives the articles deposited in return with her. The shortest and simplest method usually pursued by strangers is, to take the woman of his choice and leave the district until the ire of an infuriated parent has subsided.

2. Food.

Some of the tribes will adhere to the most disgusting varieties of food, in spite of the partial advantages of civilization with which they come in contact. Under no consideration can any of them be induced to taste vinegar a second time. Some of the Shoshonees obtain some food from settlements, but subsist chiefly upon what game and fish they can secure in addition to lizards, grasshoppers, etc. During the summer they all engage in hunting for plants which furnish a tuberous root, known to them as the yam-bí-tsi. * Their mode of preparing grasshoppers is in this wise: a fire is built covering an area of from 20 to 30 feet square, and as the material is consumed to coals and ashes, all the Indians start out and form an extensive circle, driving the grasshoppers with blankets or bunches of brush toward the centre, where they are scorched or disabled, when they are collected, dried, and ground into meal. With the addition of a small quantity of water this is worked and kneaded into dough, formed into small cakes, and baked in the sand under a fire.

Generally ground grass-seed is mixed with water, † baked, and eaten alone, but frequently it is mixed with this insect flour, giving it a better consistence. The Pah-Utes on the banks of the Colorado River use this sort of food more generally than the Shoshonees. The latter raise some corn, melons, and musk-melons, and store great quantities of piñon nuts, when in season. The Pah-Utes in the southwestern portion of Nevada, and even across the line into California, consume the larvæ of flies found

* *Yam-pa* or Yaní-pah. Fremont gives this in his report as *Anethum graveolens.*

† The natives in the interior of Australia have a similar custom of eating a paste made of ground grass-seed, *Panicum lævinode.* It is described as sweet and palatable. < "Tropical Australia," Mitchell, London, p. 98. [Jour. Anthrop. Instit., vol. vii, No. 1, 1877, p. 4. (London).]

The Congarre [Queensland] also grind grasses between two stones, and then make it into a sort of damper. They have no word for flour. See "Aboriginal Dialects of Queensland. H. Barlow." < Jour. Anthrop. Institute, vol. ii, 1873, p. 174.

upon the borders of some "alkali" lakes.* The organic matter washed ashore is soon covered with flies, where they deposit their eggs; there being not sufficient nourishment for all the worms, some die, when more eggs are deposited, and so on *ad infinitum*, until there is a belt of swarming, writhing worms from 2 to 4 feet broad, and from an inch to 3 inches in depth. This was the exact condition on the shore of Owens's Lake, California, in August, which appears to be the favorable season. At such localities the Indians congregate, scoop up and pack all that can be transported for present and future use. When thoroughly dried, it is ground into meal, and prepared and eaten as by the Shoshonees. †

The Seviches and Hualpais are as filthy in their tastes as the Pah-Utes. Although game is not scarce on the Colorado Plateau, they are often unable to secure sufficient for their wants, on account of the small number of horses in their possession, and the general absence of fire-arms. They always prefer the entrails to the meat of an antelope or deer, and they cannot be persuaded to part with the former under any conditions. The fruit of several species of Opuntia, grass-seed, gophers, dried lizards, grasshoppers, and other large insects are eaten with apparent relish.

A Hualpai woman appeared perfectly contented in eating a half-decomposed gopher, and, when offered, politely refused a small dish of canned peaches.

Many of the Hualpais warriors besmear their faces and bodies with the blood of a freshly killed antelope, then spread their fingers and draw them over the face so as to leave it striped. Where the skin is thus exposed it retains its natural dusky hue; but when the blood dries and falls off, the bleached surfaces are exposed, giving the object a hideous aspect.

The Apachès, generally, are an unsettled race, and live upon such game and fruit as they may be able to procure. The subtribe of Coyotèros, living about Camp Apachè, were dependent upon the issues served them by the government. They were furnished a certain number of head of cattle every week, which were driven away to their slaughtering-ground, where the warriors would cut the ham-strings of the animal, slit open the abdomen, and tear out the entrails and devour them when still warm, often merely pressing out the contents with their fingers. None of these delicacies (?) are ever offered the women, who must be contented with their allowance of plain meat. This custom extends also to other tribes. ‡

Their use of the "mezcal" or maguay plant is well known.§ They prepare an intoxicating beverage from the "heart" or centre of the unopened cluster of leaves, by first making a circular depression in the ground and lining it with stones, when a fire is built into it until perfectly heated; the mezcal is then piled into this receptacle, covered over with stones and earth, when another fire is built over the surface and kept up until the cores are thoroughly cooked. This may last from three to fifteen days, the time depending upon the quantity to be prepared. When the roots have been thoroughly cooked they are of a semi-gelatinous consistence; they are then crushed in vessels made for

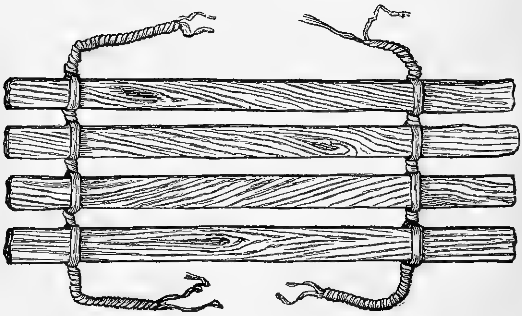
* Often a scum of organic matter is found around the margin of alkali lakes, which results, in part, from dead fish, who have come down from the streams and were overcome by the alkalinity and perished. I presume this to be one reason, as skeletons are not of uncommon occurence.

† See also "Rep. Explor. Exped. (Rocky Mts. 1842, Oregon and North Cal. 1843–44.) By Bvt. Capt. J. C. Frémont, 1845, p. 154.

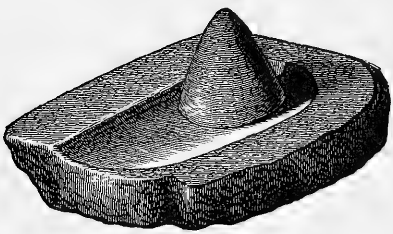
‡ Commerce of the Prairies, Gregg, New York, 1844, vol. ii, p. 296.

§ See also Pac. R. R. Rep., vol. iv, p. 9.

Apache pictograph.



Apache splint.



Metapile and metlatl.

this purpose, the liquor is poured off into other vessels, where it is kept until fermentation sets in, when they call together the tribe or band and have a dance, which results in a drunken and obscene carousal.

The Pimos, Maricopas, and others living on the Gila River prepare a similar drink from the fruit of the *Cereus giganteus* and several other *Cacti.* Horse or mule flesh is always a desirable "tit-bit" if obtainable.

3. Fire.

At Belmont, Nevada, I found a small *rancheria* of Shoshonees, who informed me that previous to the development of the mines or the advent of the whites they were obliged to keep on hand a supply of dry wood and pine knots for the purpose of igniting and transporting fire, as the art of making it was unknown to them. This appeared remarkable, and I made inquiry among those of the settlers who had been there longest. The Canfield Brothers, who were superintendents of the New York Mining Company, verified the statement so far that they always saw the Indians keeping up perpetual camp-fires, and when on a short march would transport burning brands, which they guarded with the most jealous care. Women were usually detailed for this duty.

Captain Sitgreaves* says: "The custom still prevails among them [Mojaves] of carrying a firebrand in the hand in cold weather, which is mentioned in the account of Coronado's expedition in 1540, and induced those discoverers to give to the river the name of Rio del Tizon." Whether this custom is still practiced I am unable to say. The Apachès near Tucson never move about at night unless armed with a brand or torch. This is induced both through fear and superstition.

4. Utensils and weapons.

But few articles are manufactured of stone at the present day by any of the tribes under consideration, as they have, to a greater or lesser extent, availed themselves of the advantages offered by enterprising suttlers and traders. Pipes made at Yankton and Sioux City, Dak., of the red pipe-stone (catlinite) have found their way to Nevada through these channels and through the Crows, with whom the Shoshonees are upon friendly terms. Most of the Indians obtain the common "plug" tobacco, which they cut up and mix with the inner bark of the Red Osier. In the southern region of Nevada I have seen the dried leaves of *Nicotiana attenuata* (Torr.) used in the pipe. The Seviches, when they can obtain paper, are fond of making cigarettes, a custom learned from the Indians who come in contact with the Mexicans.

Most of the Pah-Utes grind their corn and grass-seed on flattened stones with pestles, and, in some instances, with metlatls.† Baking is done under a layer of sand, upon which a fire is built, as with the Mojaves, Pah-Utes, and some of the Shoshonees, and others. The manufacture of stone arrow-heads is still carried on by the Coyoterò Apachès. Various species of siliceous materials are employed. The triangular shape is characteristic of this tribe. The dart is fastened to the shaft by means of a dark reddish-brown vegetable gum and sinew

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* Rep. Exped. Zuni and Colorado River, Capt. L. Sitgreaves, Wash., 1833, p. 18.

† The word metate has been generally used, but as it is of Aztec origin and slightly corrupted, I propose to use the proper term, metlatl, as above. The metalpile is gener-

threads, which are brought forward over the two basal apices, above which there are usually two slight notches for their reception. Fragments of so-called porter-bottles are frequently utilized in the manufacture of arrow-heads, making an effectual but brittle weapon. There is no question but that these Indians sometimes poison some of their arrows. I have been shown arrows, and have had them offered me, which the owners informed me were poisoned, so that I should be careful in handling them. Dr. Soulé, elsewhere referred to, informs me of the same fact; and Dr. Elliott Coues, of the Army, who has had ample experience in treating arrow-wounds, informs me of a case which he had every reason to believe to have been caused by a poisoned one.* Stevens says:† "The arrow-heads of the Shoshonees of North America, said to be poisoned, are tied on purposely with gut in such a manner as to remain when the shaft is withdrawn." This may have been the custom, but I have not heard of it as being in practice now.

The Pah-Utes of Owen's Valley, Cal., and of Southwestern Nevada sometimes employ chert and "bottle-glass" arrow-heads. That they do not utilize the obsidian found in large quantities east of Siver Peak and Red Mountain, Nevada, is rather singular, although this locality is well-known to them. A variety of red obsidian occurs in the upper extremity of Owen's Valley, which Mr. Partz subjected to partial analysis several years ago, and was inclined to attribute the color due to suboxide of copper. The same gentleman says he has found bowlders of black obsidian several miles south of Mono Lake, which would weigh from 100 to 150 pounds.

The Mojaves are to some extent possessors of fire-arms, though bows and arrows are frequently seen. A principal weapon in hand-to-hand encounters is a club, with which nearly every warrior is armed. These are known to the settlers under the unpoetical appellation of potato-mashers. The sharp ends of broken bayonets, or some which they obtain at the military stations, are fitted to long poles, and used as lances or spears. The Apachès use similar weapons when the necessary points can be obtained.

The Seviches in the northwestern portion of theColorado Plateau still manufacture stone arrow-heads. Among this tribe I saw one made of gold-bearing quartz, in which were several fine viens of the native metal. All efforts to discover the origin of the specimen or the locality where it had been obtained proved fruitless.

The Shoshonees use stone arrow-heads very rarely. The typical form was triangular, and not knife-shaped, as is stated in Jones's report.‡ The question is with what tribe did this peculiar form originate as a typ-

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ally in the form of a rolling-pin, an elongated cylindrical stone, tapering toward both ends, but as the pestle was a rare form for the southwestern tribes to use, I have figured it instead of the common metalpile. This form of pestles was very common among the Delawares in Pennsylvania. The Aztecs used the metlatl of nearly the same form as is found to-day among the Pah-Utes and other tribes in Nevada and Arizona. Tylor says, "The metate is a sort of little table, hewn out of basalt, with four little feet, and its surface is curved from the ends to the middle." Tylor's Anahuac, London, 1861, p. 88. In Appendix, p. 336, he gives the word as from the Aztec. The manner of using is illustrated on plate facing p. 201 (q. v).

* Med. and Surg. Reporter, vol. xiv, No. 17, pp. 321–324. A paper, by the author of the present article, entitled "Notes on Poisoned Arrows," was read by Dr. Coues, U. S. A., before the Phil. Soc., Wash., D. C., Jan. 5, 1877, which was afterward published in the "Daily Rocky Mt. News," Denver, Col., Jan. 17, 1878.

† Flint Chips. Ed. T. Stevens, London, 1870, p. 260.

‡ Rep. upon the Reconn. of Western Wyoming, including Yellowstone Nat. Park, Wm. A. Jones, U. S. Engrs., Wash., 1875, p. 264 (fig.).

ical one? During the season of 1872–'73 I made thorough examinations of the bone and sand heaps, known at the locality where they were found (Grand River, Dakota Territory) as the "Old Ree Villages," during which I found first one of black hornstone mixed up with numerous fragments and splinters of mammalian bones and pieces of pottery; and afterward learned of the existence of numerous specimens of this form. Evidently the one figured in the report above named was transported through aboriginal barter, or the shape may have been copied after having seen those among the Arickarees. Specimens of nearly this form are frequently found in the old "work-shops," or arrow-makers' camps, in various sections of the country, which appear to be mere coincidences. The Shoshonees sometimes manufacture their own fish-hooks, by taking a splinter of bone and attaching another and a smaller piece at one end, at an angle of about 40°, by means of silver threads. For catching the larger *salmon trout* with which Maggie Creek, Independence Creek, and the Owyhee abound they answer the purpose very well.

5. Medicine and incantations.

As a rule, the aborigines have immense faith in the imaginary supernatural power of a favored few. Those who are so entrusted with the temporal welfare of the tribe usually abuse that confidence and become rogues, if they are not already the most scheming villains, through which tact and craftiness they generally attain the position of an acknowledged "medicine-man." Many of the chiefs secure and retain their authoritative and undisputed control of their respective bands merely because they are more domineering in disposition, which is backed up by a limited amount of courage, so that they are, to a great extent, obeyed and looked upon with reverence and awe. Under such circumstances I found the Seviches. One man appeared the centre, from which, a short time previous, emanated all plans and schemes for the adoption and prosecution of the tribe. His power was admitted, but what should cause such implicit obedience? His mismanagement finally broke the charm, and he fell to the level of the common herd. The reason of his influence was attributed to various sources, one of which I submit for what it is worth. The story may or may not have originated with the Indians, but when they were questioned regarding their having been duped, they neither admitted the fact nor denied it, which would seem that there must have been a cause for something.

Charles Spencer, an interpreter, who had for many years been connected with the mail-service, gave me the following narration: This chief was of humble birth, and as he had great desire to become a "medicine-man," he waited until an opportunity presented itself. A custom which had always been in practice in the tribe required a "doctor" to specify in advance the number of days required for the recovery of his patient. Failing in this three times, *i. e.*, should the patient, on the contrary, die, the life of the medical man paid the penalty.* The would-be chief, fear-

* Sir John Lubbock says the Macas Indians (Equador) have doctors, whose remedies, however, are mainly, if not entirely, magical. If they fail to effect a cure, they are sometimes put to death themselves. <Jour. Anthrop. Institut., vol. iii, 1874, p. 31. [Note on the Macas Indians (Equador).]

Lieutenant Musters, R. N., says "The position of wizard or doctor [Ahonicanka, or Tchonek—Patagonians proper] is not a very desirable one, as in the event of his prognosticating a success in a war expedition, or cessation in sickness, or any other event, which is not realized, the chief will not unfrequently have him killed." On the Races of Patagonia. <Jour. Anthrop. Instit., vol. i, 1871, pp. 193–207.

ing the worst upon such a trial, decided to attempt a new form of intimidation. He announced that he was bullet-proof, and offered to allow any Indian to shoot at him at a respectable distance, provided, always, that he be permitted to load the gun. The trick was a success, which depended upon this reason, that in casting the bullets a piece of paper was laid in the mould so as to cut the metal into hemispheres. When the metal and paper were removed from the mould, the two pieces of lead were placed together and the edges pressed down with the back of a knife so as to cause sufficient lapping to make them adhere. In loading, these were separated, and the fragments, on account of their semi-spherical proportions, diverged sufficiently to cause no special danger to the one fired at. After awhile the deception became known, when the tribe demanded the enforcement of the old usage. So when a patient was submitted to his charge, he would almost invariably prophesy a fatal termination upon a given day. During this time infusions were administered, which were no doubt harmless; but should the patient show signs of recovery when death had been prophesied, another infusion was substituted, which terminated to the credit of the "doctor." This trickery was discovered, but the very audacity of the perpetrator saved his life.

It is next to impossible for a tribe so low in the scale of civilization to have so much judgment in matters of this sort, and I therefore do not claim that much credence can be placed upon the tale as given.

I was informed but a short time since by Mr. Partz, of California, that during a recent outbreak of small-pox among the Pah-Utes, of Owen's Valley, California, and Southwestern Nevada, many members of affected families were secretly put out of the way, as the disease is considered a curse, and the sooner the afflicted family is disposed of the sooner will the evil be removed. In what manner the victims disappeared cannot be discovered; sufficient is it to know that they have forever left their terrestrial haunts.

I witnessed a cure for colic in a Mojave which had been induced by eating an over quantity of horse-flesh. A Pah-Ute, from Rio Virgen, presented himself as a "medicine-man" who, for the fee of one blanket, offered to remove the evil spirit. The patient was laid upon the sand face downwards, when the Pah-Ute placed one of his feet upon the former's back, over the afflicted spot; then pressing it gently as if he were kneading it, he would accompany the movement with a mournful chant, grasping the while at an imaginary object near his patient and pretending to throw it violently into the air. After this had been continued for nearly an hour, he rolled the patient over on his back, taking the head and shoulders into his arms and sang, rocking himself from side to side, repeating short phrases, and exorcising the spirit to leave; then after a time, he would return to his former manner of treatment with renewed vigor until about three hours had been consumed. When the Mojave considered himself relieved, the Pah-Ute received his pay and departed. During this performance great silence was observed, and we "who were not of them" were frequently admonished for laughing.

The Mojaves, since the arrival of the United States troops and the floating element which usually precedes civilization, have been fearfully afflicted with venereal diseases. These Indians are not noted for strict adherence to marital vows or laws, neither are the girls for chastity, thus affording an opportunity for remarkable and rapid progress of disease, which has been doing more toward the gradual extinction of the race than all other causes combined. They claim to gain relief in taking certain quantities of the saline efflorescences which occur on the dry,

muddy banks of the Colorado River. This efflorescence consists chiefly of the following ingredients: sodium chloride, magnesium chloride, and sodium sulphate, with which the water is largely impregnated, and which are left by the evaporation of the water during summer and autumn. No salutary effects can be derived from this in the hands of the Indians, and Dr. Stirling, post surgeon at Camp Mojave, says he has never seen any perceptible benefit during his residence there.

The Apachè Mojaves and Coyotèros employ several varieties of herbs and barks which I was unable to identify owing to the dried, crushed, and semi-pulverulent condition in which I saw them. Dr. Loëw* says that the bark of *Populus tremuloides* is used by the Indians as a remedy against fever and ague, though to what tribes in particular this statement refers, is not stated

Dr. Milan Soulé, who was for several years post surgeon at Camp Apache, informed me that the Coyotèros were in the habit of tying their women who were in labor against a tree with the hands above the head, and left in this position until the child was born. He says this cruelty does not appear to affect them in any perceptible manner, as they are a much shorter time in resuming their usual avocations than the most robust white woman that he has known.

The Coyotèros employ a splint in fractures and gunshot injuries of the extremities, which is well worth noting. The appliance which I was shown had been used by a warrior in a case of comminuted fracture of the middle third of the left humerus. It consisted of twelve or fifteen small strips of cedar wood, each of which was about a quarter of an inch thick, three-fourths of an inch wide, and from 6 to 8 inches long. About one inch and a half from the ends the slats were secured by means of their sinew bands, so as to leave intervening spaces of about a quarter of an inch. The splint was then fitted around the arm and drawn taut by means of the loose sinew ends and tied. Through the spaces water could be applied to the wound without injury to the appliance, and a free discharge was likewise secured.

6. Disposition of the dead.

The Shoshonees of the upper portion of Nevada are not known to have at any time practised cremation. In Independence Valley, under a deserted and demolished *wickeup* or "brush tent," I found the dried-up corpse of a boy about twelve years of age. The body had been here for at least six weeks, according to information received, and presented a shrivelled and hideous appearance. The dryness of the atmosphere prevented decomposition. The Indians in this region usually leave the body when life terminates, merely throwing over it such rubbish as may be at hand, or the remains of their primitive shelter tents, which are mostly composed of small branches, leaves, grass, &c.

The Pah-Utes in California just west of Columbus, Nev., are not known to practise cremation. Mr. Julius Partz, of Partzwick, Cal., says that during his residence of twelve years he has not been able to obtain any information that they do or ever did. Mr. Wetherill, who has spent twenty years in that region affirms the statement. They bury their dead in a grave about 4 or 5 feet deep, depositing with the body small quantities of seeds, fruit, and, when possible, several coins. My halt of a few hours was not sufficient to obtain much information, and none from personal observation.

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* Loëw's List of Plants of Med. and Tech. Use. < U. S. Geograph. Surv. West of 100th Mer., vol. iii, p. 608.

The Pah-Utes, known as the Cottonwood, Corn Creek, Spring Mountain, and Pah-rimp Spring Indians, cremate their dead.* The following extract has allusion to the Spring Mountain Pah-Utes, which description answers for the others:

"The tract of country alluded to, as occupied by this sub-tribe of Pah-Utes, lies between 115° and 115° 35′ west longitude, and latitude north 35° and 36°; Spring Mountain being their stronghold, and is located just north of the 'old Spanish Trail.' By means of an interpreter, I obtained the following information: Upon the death of one of these Indians, a pile of wood is prepared in the immediate vicinity; this is so arranged as to form a rectangle, to the height of from 2 to 3 feet. The corpse is laid upon this, when the fire is started, after which wood is continually thrown across the pile until the body is reduced as much as possible. Mesquite, pine, and cedar is usually employed, and forms excellent coals and an intense heat. All the remaining property—as wearing apparel, arms, blankets, dogs, and horse (if the deceased possessed any)—is also burnt. These last-named valuables, I have no doubt, may be represented to have been burnt, as the number of horses among the tribe is very small. Although, according to their belief, when an Indian dies his spirit goes to the East, which they consider the 'White man's hunting ground,' and where he would be unable to hunt were his spirit deprived of these valuable aids. The remains are then *covered with earth*, whether really *buried* I could not ascertain."

Since the above was written I have been informed that the ashes are gathered, placed into a piece of cloth or blanket, and buried.

It appears singular that two subtribes of one nation, speaking the same language or dialect, should vary so much in such an important rite. By way of illustration and to show some additional points of interest connected with this subject, I will briefly allude to the mode practised by the Pah-Utes at Marysville, Cal. As soon as an Indian is taken sick all the rest of the band remove their effects a short distance to a temporary encampment. The sufferer is left in his tent or *wickeup*, where he is constantly supplied with food and other necessaries by one or more of his relatives or friends. If death ensues, the corpse is wrapped in a blanket and tied with ropes made of grass, so as to straighten the body as much as possible. Pine wood is then collected, a pile erected about 8 feet long, 4 feet broad, and from 2 to 4 feet in height, the quantity taken being sufficient to consume the body. All the members of the band (personal enemies excepted) then form a circle around the pile, upon which the pall-bearers have deposited the corpse; the pile is ignited, and as the whole is being consumed, the widow or widower, as the case may be, advances and besmears the face with the black exudation which results from the blood, grease, and resin, intimating that no offers of marriage will be received or given as long as any traces remain thereof; the ashes of the body are then carefully collected, put into a small bag made of rushes or a piece of cloth or blanket, and buried in a suitable locality in the neighborhood.

The Mojaves, at Camp Mojave, on the Colorado River, Arizona, bury their dead in the sandy hills six or seven miles northeast of the settlement. They never bury their dead on the western side of the river, as they consider that region—especially the mountain-peaks—the abode of the souls of bad Indians and evil spirits. The reason of this superstition can no doubt be attributed to the following. Most of the elevated points of land are daily subjected to severe showers, accompanied by

* Pah-Ute Cremation. Read before the Am. Phil. Soc., Dec. 4th, 1874. [W. J. H.]

the most terrific electrical displays. The hot air of the surrounding valleys and deserts ascends the mountain-sides, where it condenses by coming in contact with a cooler medium, forming vapor which finally descends in copious precipitation. These showers are nearly of daily occurrence, but, owing to the sandy and porous nature of the soil, the water is instantly absorbed, and but little reaches the base of the mountains over the surface. The Indians being naturally superstitious, such terrific but short storms, attended with extraordinary flashes of lightning and the continued rumbling sounds of thunder in one locality, are to them inexplicable, and they therefore attribute it to incensed gods and evil beings.

The Coyotèros, upon the death of a member of the tribe, partially wrap up the corpse and deposit it into the cavity left by the removal of a small rock or the stump of a tree; after the body has been crammed into the smallest possible space the rock or stump is again rolled into its former position, when a number of stones are placed around the base to keep out the coyotès. The nearest of kin usually mourn for the period of one month, during that time giving utterance at intervals to the most dismal lamentations which are apparently sincere. During the day this obligation is frequently neglected or forgotten, but when the mourner is reminded of his duty he renews his howling with evident interest. This custom of mourning for the period of thirty days corresponds to that formerly observed by the Natchez.*

7. Stone circles and signals.

On the trail leading from Eureka southward towards Hot Spring Cañon and Belmont, Nev., I saw at various localities the remains of stone circles which had been placed there by the Shoshonees. The ranges of mountains and foot-hills generally are covered with piñon pines (*Pinus edulis*, Engelm.), and the Indians who occupy small patches of soil for permanent encampments are in the habit of selecting suitable places along the foot-trails for gathering the fruit of this tree and storing it for future use, as well as for such of the tribe as may be unable to reach camp, or in want of food. All the Shoshonees in the southern interior of Nevada provide for one another in this manner. Their mode of doing so is in this wise: a number of stones are collected, each of them from one-half to one cubic foot in bulk, which are arranged in the shape of a circle having a diameter of from 2 to 4 feet. When fruit is abundant (which happens but once in three years in respective localities), it is collected and piled into this circle, covered over with sticks and leaves, and finally a layer of earth, so as to secure them from rodents and birds. Still, the former more frequently discover these deposits than the benighted warrior for whom they are intended. The Shoshonees do not know of any circles connected with religious or burial ceremonies. Circles of similar construction are sometimes found upon elevated points of land, where they are located as a post from which a good view of the surrounding country can be obtained. Here sentinels are posted, or a voluntary watcher may take his station to notify his camp of the approach of game or of strangers, where his time is employed in making or mending bows, arrows, or other trappings. Frequently the ground around such watch-stations is literally covered with chirt or flint chippings. These, however, are not of very recent date, as stone darts are not as numerous as they were previous

* Jones's citation of Father le Petit's account of the Natchez Indians. <Explor. Aborig. Rem. of Tenn., p. 21. [S. C. No. 259.]

to their communication with the whites. Nevertheless, these siliceous chips and flakes are found more or less about all such stations, and from the surface accumulation we are enabled to form some idea of their age. None have been found throughout the region under consideration that would indicate a greater existence than from forty to fifty years.

A circle of this sort is described and figured in the "Report upon the Reconnaissance of Northwestern Wyoming, 1873, &c., Capt. W. A. Jones, United States Engineers," p. 264, which is considered to be a relic of a race of sun-worshippers. Dr. F. M. Endlich, of this Survey, has observed similar circles throughout the northern Shoshonee country, in and about which he has invariably found flint chippings upon the removal of surface accumulations of earth, sand, or other materials. This has been the result of my examinations in the Pah-Ute country of Southwestern Nevada, where these Indians had similar "lookout" stations in former times. The Hualpai, of Arizona, are also in the habit of stationing sentinels upon elevated ridges or buttes, where stones have been arranged in some manner so as to indicate at a glance for what purpose the location is intended. Similar circles are constructed by the Dakotas on the Upper Missouri. Any elevated locality in the immediate vicinity of an encampment will furnish, upon examination, circles or other forms of stones. From such posts of observation signals can be transmitted to camp, imparting information as satisfactorily as if delivered verbally.

It is a well known fact that the Indians throughout the country have a most remarkable manner of transmitting information quickly and accurately. The tribes of the Southwest signal by means of smoke by day and fire by night. The Dakotas even mix their combustibles so as to cause different shades of smoke; using dried grass for the lightest and pine-leaves for the darkest, a mixture of the two in proper proportions causing an intermediate shade. These, with their manner of causing a column or several puffs of smoke, furnish materials for a variety of combinations and effects. At night a continued fire and puffs or flashes are used. Frequently a bunch of grass is tied to an arrow, lit at the top, and fired into the air. The Aztecs signalled to one another by means of fire during the siege of the city of Mexico,* and by this means likewise summoned their forces.

8. POTTERY AND PICTOGRAPHS.

In the White Mountains, between the towns of Columbus, Nev., and Benton, Cal., are varied remains of pictographs or rock drawings. These represent odd figures of men, animals, and other unintelligible characters. The Pah-Utes, who are located on the California side, and the Shoshonees near Columbus, are unacquainted with them. These remains of a former race are more numerous as we proceed southward, and they evidently belong to the same group who have left such numerous and interesting evidences of a former extensive population in Arizona. About 20 miles south of Benton the stage-road passes through a narrow defile, upon either side of which the perpendicular walls rise to a height

* Verdad. Hist. de los Suc. de la Conquesta de la Nueva-España. Per el Capitan Bernal Diaz del Castillo. <Historiadores prim. de Indias. Don Enrique de Vedia. Tom. Seg., p. 117, Madrid, 1853.

[Bib. Ant. Esp., vol. i, 52.]

A description is given on telegraphing by means of smoke by Capt. Randolph B. Marcy, U. S. Army. <"The Prairie Traveller," etc., New York, 1859, pp. 226–229.

Note on accuracy in signals is also given by Josiah Gregg. <Commerce of the Prairies, etc., New York, vol. ii, 1844, p. 295.

of about 40 or 50 feet. These walls are literally covered with carvings, resembling those found in the mountains just named.

The next locality which I found to bear any relics of this sort was on the trail from Peach Springs to Bill Williams Mountain, Arizona; the most prominent one being portion of a small basaltic column protruding from the surface, upon which was the representation of a sun, besides other odd characters. The former was composed of a circle about 3 inches in diameter, about an inch beyond the periphery of which were seven or eight lines radiating from it. Some of these lines were nearly obliterated, and could only be distinguished upon the closest scrutiny. That side of column bearing any characters whatever faced the east.

I do not believe that all of these pictographic remains have anything to do with historical records. Many of the children of the Pah-Utes in Southern Nevada are in the habit of chipping upon large stones such figures as may strike their fancy. Upon the hard flat sand-beds near Spring Mountain our whole outfit was recorded in this way. Mr. W. H. Jackson, of your Survey, states that the Zuñi children pass their time in cutting and chipping various characters and figures upon the rocks. His experience and investigations among the various tribes of New Mexico and adjacent regions is entitled to some considerations, at least in this respect.

The accompanying drawings illustrate some rock-cuttings made by the Coyotèros, and found near Camp Apachè. They are modern, and show their mode of conveying ideas. The principal figure represents a pack-mule. The four lines beneath show the additional number of animals used for this purpose, connected with the same train. The star is intended to represent the sun, the accompanying number of spots represent the number of *suns* or days the party spent in the territory of the Coyotèros. The pictograph was not intended as a record, but was made for pastime and the want of better occupation. The remains of an extensive occupation of the territory became apparent in the region from Postal's Ranch southward for a distance of about 15 miles toward Prescott. This valley is about 10 miles broad in the middle, and throughout the entire western portion of it are found small flattened elevations of earth containing numerous fragments of pottery. These heaps of *débris* appear to be the remains of ancient adobe dwellings, which were located from 20 to 40 feet apart in all directions. Along the western ridge can be traced an arroyo or water-ditch, which is at this day at least 40 feet above the level of any springs or streams. This canal can be traced northward, but not beyond the limits of the valley itself. North of the valley are large beds of dried-up streams, which were no doubt the source from which water was obtained for irrigation. It has been supposed that the climatic changes were brought about by some geological convulsions, which resulted in the gradual sterility and depopulation of this ancient region. Facts, which become more apparent every day in other countries, indicate rather that this former people caused their own destruction, unconsciously, by the *deboscation* of the regions thus affected. In other places throughout Arizona and New Mexico, where we find the remains of large settlements and towns, we have evidences of large water-courses filled with sand and rounded pebbles and bowlders, showing that the country must have been excellent for agriculture in remote times. Here, where the country is undulating or hilly, and geologically perfect for the growth of forests, we find nothing but a few stunted cedars, pines, or cottonwoods. Cedar rafters examined in some of the cliff remains indicate trees of large size;

these, employed in building and for fuel, in time disappeared, when the soil became so dried as not to be able to afford the requisite conditions for rain-fall. We have not only to look to Germany, to France, and to Oriental countries, but our own country affords numerous examples where the gradual cutting away of timber has so affected the annual rain-fall as to injure crops very materially, and to the extent of thousands of dollars. Dr. G. A. Boardman, of Maine, has had a large spring disappear entirely within a period of about twenty years merely through the clearing of one or two small hills. Within twelve years, streams of considerable size have nearly disappeared from the same cause in Eastern Pennsylvania. In this locality the crops are more affected by blight, mildew, and other diseases of a similar nature than formerly, and the farmers are beginning to realize the danger incurred through this wilful or negligent destruction of forests.

Upon the fragments of pottery found throughout Arizona there appears to be a similarity of designs. The styles of ornamentation upon those found at Postal's Ranch correspond in every particular with those occurring in and about the cliff dwellings near Camp Verdè, 70 miles east. That the Cliff-Dwellers occupied this valley for raising their crops and for agricultural purposes generally seems evident from the fact that it is the only really favorable district, but one, found within convenient distance from the cliff remains, and also the nearest patch of irrigable land upon which we find any traces of former occupation.

The cliff dwellings appear to have been occupied during the winter season or in times of danger from hostile incursions of neighboring tribes. A description of the most important is given elsewhere.

Fragments of pottery collected in the valley from Postal's Ranch southward to near Prescott, on the banks of the Colorado Chiquito, near the mouth of the Rio Puerco, and along Beaver Creek from near Camp Verdè up to Montezuma Wells, show a general similarity of consistence and ornamentation. Most of the pieces have a smooth exterior, frequently, or I might say usually, enamelled, sometimes having the designs cut into the material as if it had been done with a pointed stick.* Imprints of finger-nails sometimes occur, as well as the impressions of the wicker-work in which the vessels were found. The specimens are now in the National Museum, and bear an exact resemblance to those figured by Mr. Thomas Ewbank.† The glazing or enamelling is generally of a dark bluish-black or brown color, although other tints are not of unfrequent occurrence, such as gray, red, and, rarely, white. The most remarkable feature in the designs is, that there are numerous facsimiles of those found upon the walls of the ruins at Mitla, in ancient Anahuac. This gives one reason to presume that the Moqui, Zuñi, and Pueblos were more closely allied in remote times, and that to this alliance belonged the Cliff Dwellers, whose identity appears to have merged with the Aztecs.‡ The general styles of architecture and the ceramic art seem very closely allied between that of the Moquis, Pueblos, and Cliff-Builders, and with better reason than that the Seviches and Hualpais should be two of the ancient Moqui-Pueblos, which is well proven

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* Fragments bearing similar indentations and impressions occur in the remains of the "Old Ree Villages" at Grand River, D. T. See "Ancient Hearths and Mod. Ind. Remains," etc., Pro. Bos. Soc. Nat. Hist., vol. xviii. Dec. 15, 1875, pp. 209–212.

† Lieutenant Whipple's Report upon the Indian Tribes, pp. 48, 49. <Pac. R. R. Report, vol. iii,

‡ The Aztecs point to the northwest as the source of their migrations, and Von Humboldt, ignorant of the existence of any ruins, supposed them to have come from that direction.

that such is the case.* These two tribes are as low in the scale of civilization as any tribes found in the Southwest; are ignorant of agriculture and the manufacture of pottery; whereas the Moqui cultivate large areas of soil and continue to produce some really excellent examples of ceramic art.

What traditions exist at this day among the tribes of Arizona regarding Montezuma appear to have originated with the early Spanish explorers. No reliance can be placed upon them, at least from which we can deduce any theory regarding their former history.

9. Ruins.

Remains of foundation-walls exist in considerable numbers on the eastern banks of the Colorado Chiquito.† Upon these, more recent structures had been erected of adobe and wood, which have long since gone to decay. Immense quantities of broken pottery lie scattered over the ground, among which are numerous fragments of obsidian, carnelian, and other varieties of silicious stones, foreign to the soil.

Several miles north of Camp Verdè, on the west bank of Beaver Creek, the limestone wall forms a perpendicular escarpment about 100 feet high.

About half-way between the summit and the base of this, into an excavation either natural or artificial, is built a large and imposing cliff fortress. I say fortress, from the fact that all the cliff dwellings from this locality upward along the stream to Montezuma Wells, a distance of about 6 or 8 miles, are very small, containing but a single room (very rarely two), the dimensions of which vary from 4 to 8 feet square and from 3 to 5 feet high. At a short distance they appear like swallow-nests, rather than habitations at one time occupied by human beings.

The fortress is about 30 or 35 feet in height, each story receding several feet; the horizontal distance of the front wall is about 50 feet, the walls being built nearly out to the face of the escarpment. There is a square tower in the middle front of the lower wall, through which I found the only means of access. The tower or bastion is nearly 6 feet square, the first floor being at present so covered with guano and bat-lime that it is difficult to ascertain the exact dimensions as regards height. There is an opening in the second floor of the bastion through which I had to crawl before being able to gain an entrance to the main rooms above. The floors are constructed of logs, about one foot thick, which had been partly flattened above and below by rude cutting-tools. Over these are laid, at right angles, thin saplings of cedar, which are in succession covered by layers of dirt, fragments of pottery, and bird and bat manure. In the second story, after digging down to a depth of over 2 feet, we reached the floor. The second story is divided into several different apartments, averaging from 8 to 10 feet in length and about 6 feet in depth. The

* Leroux gives the following in Lieutenant Whipple's Report upon the Indian Tribes. <Pac. R. R. Rep. vol. iii., p. 13.:

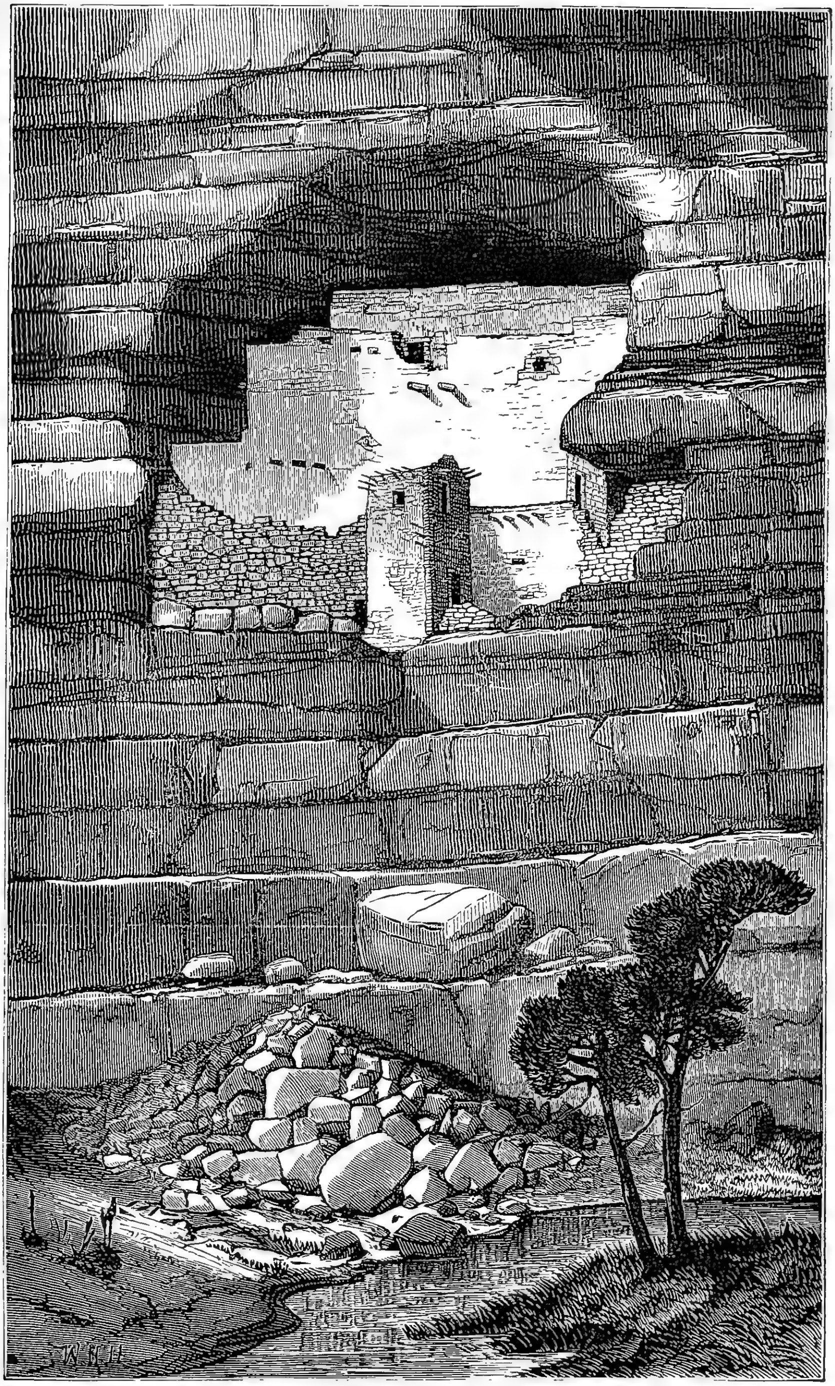
Tribal names.	In Zuñi.
Guāl-pí	Wathl-pì-è.
Shi-wĭn-nà	Shi-wĭn-è-wa.

[The syllables *Gual* and *Hual* are pronounced as in Spanish.]

† Lieutenant Whipple notices these in his itinerary report. <Pac. R R. Rep., vol. iii, p. 76, 77.

openings leading from one to the other are low and scarcely large enough to admit a man of ordinary stature. The roof of the second story forms the floor for a sort of parapet; the wall which extends up from the story below being about 4 feet high. Through this are several port-holes, 3 or 4 inches square on the inner side and over a foot on the outer; through these arrows could very easily have been fired, as the shape of the openings permits of considerable shifting in firing either toward the right or left. Back of this parapet is a large opening leading into the rocks, which appears as if it might have been used as a store-room for food. At the mouth of this the fires had evidently been built, as there is a space about 6 feet long and 4 broad, which consists of the natural formation. The wall above was darkened, but this may have been caused by more recent visitors. As will be seen in the accompanying illustration, it is probable that the tower extended all the way to the top of the entire structure, or nearly so. Two rafters, protruding from the middle wall, are still in position, which evidently served as a partial hold or support. The door or opening in the unplastered stone wall beyond the tower leads into that space between the first and second walls, and has no communication with any other apartments. The door partially visible in the upper posterior wall is the one leading to the supposed hearth and store-room. There are visible entrances to other rooms upon the same level, but they are literally filled with the materials before named, in addition to fragments of the rock, which is gradually crumbling and breaking off in fragments through disintegration. The lintels over the door-ways are generally of cedar, and in as substantial a condition as when first placed there. The outer walls generally had been plastered, and in but few places has this fallen off. The stones composing the walls are neatly and closely laid and fitted, and actually cemented together with mortar. By the natural breaking away of the rocks below the building, the place has become more accessible than it appears to have been when regularly occupied, when rope ladders or similar contrivances were probably necessary.

"Montezuma Wells" is so-called from the fact that it is an oblong depression about 60 or 70 feet deep, having perpendicular walls, at the bottom of which is a deep spring of clear water. Around the base is a line of *débris*, consisting chiefly of rocks, between which and the water's edge are a few scattering sycamores. The excavation is about 100 yards in its greater diameter and about 60 yards in its lesser. There is but one point at which a descent can be made, which passage is guarded by small cliff-dwellings. In various depressions these small habitations are located, giving the place a very singular appearance. From the base of the excavation on the eastern side there is a narrow and low tunnel leading out to the banks of Beaver Creek; the entire distance is about 60 or 80 feet. The origin of this singular geological formation was evidently due to the gradual solution of the limestone by the water having at some time or other been charged with some acid gases or mineral ingredients. The settlement within this natural enclosure was no doubt a retreat in times of danger, as the sloping surface receding from it is covered with ruins of former structures, over the remains of which, and throughout considerable surface beyond, the soil is covered with numerous fragments of beautifully glazed and incised pottery. Flint and carnelian flakes, weapons, and other remains occur in considerable quantities. The land surrounding this locality is excellect for agricultural purposes, and it appears to have been at one time nnder cultivation. Wherever one turns scattered pieces of pottery are visible, giving either proof of a very large settlement, or one that lasted for many years.



Cliff Fortress.

PART IV.

PALÆONTOLOGY AND ZOÖLOGY.

REPORT OF LEO LESQUEREUX.

REMARKS ON SPECIMENS OF CRETACEOUS AND TERTIARY PLANTS SECURED BY THE SURVEY IN 1877; WITH A LIST OF THE SPECIES HITHERTO DESCRIBED.

By Leo Lesquereux.

Part I.—REMARKS ON SPECIMENS SECURED IN 1877.

Until the end of the season of exploration of the Geological Survey of the Territories in 1877, few specimens of fossil plants had been received for examination. Some were sent by Passed Assistant Engineer H. C. Beckwith, United States Navy, from the Cretaceous strata at the foot of the Rocky Mountains, near Morrison, Colo., and a few by Rev. Arthur Lakes, from the Eocene of Golden. These have been examined and figured, but they are too few in number for a separate report.

Near the end of the past year I received from the Upper Tertiary of Florissant an immense amount of specimens, mostly obtained by Prof. Samuel H. Scudder. The examination of these materials is begun, but the materials are so abundant that a careful determination and description of them will demand much time, and I can now give merely a general and superficial account of what these specimens represent. With those of the Cretaceous, they may be all together published in a future report.

CRETACEOUS.

The Cretaceous species from Mr. Beckwith's specimens are interesting on two points. They are the first Cretaceous plants found near the base of the Rocky Mountains,* and by their relation and identity to some species of the Dakota Group, they prove the continuity of this formation from the point where it passes under the Upper Cretaceous and Tertiary strata in Nebraska and Kansas to the base of the Rocky Mountains, where it becomes exposed again by the upthrow of the hog-backs. And then they are highly interesting by the species or types which they represent, some of them remarkably beautiful and new.

The geological age of the formation, and its identity with that of the Dakota Group, is positively indicated by the presence of *Sassafras Cretaceum*, Newb., *Magnolia Capellini*, Heer, *Salix proteæfolia*, Lesqx., and of species of *Aralia*,—one, *Aralia Towneri*, Lesqx.; another, similar to *Aralia concreta*, Lesqx., differing merely by the division of the leaves into three instead of five lobes. By this division, the leaves are intermediate in characters between *Aralia tripartita*, Lesqx., of the Annual Report of 1874, p. 348, pl. i, fig. 1, and *Aralia concreta*, of the same report, p. 349, pl. iv, figs. 2–4. In the same genus we have also, from the same locality, near Morrison, where the plant-bearing strata are somewhat higher than those where the bones of great Saurians have been discovered, leaves of an *Aralia* so closely allied to the one described by Professor Heer as *Aralia formosa*, from the Cretaceous of Moletin, Ger-

[* Compare, however, Ann. Rep. of this Survey for 1873, 1874, p. 196.—Ed.]

many, that I do not see as yet any characters to authorize a specific distinction. The American leaves are somewhat larger, with broader lobes, the middle one longer than the lateral ones. In Heer's species, the middle lobe is shorter, but there is no other apparent difference, the nervation being the same, and the borders of the leaves crenulate in exactly the same manner. By the leaves, therefore, we have proof of the geological relation of the Dakota Group with the Cretaceous strata exposed at the base of the Rocky Mountains, and also of the Cretaceous of Colorado with that of Europe. The Moletin formations, according to Heer, represent the *Lower Quadersandstein*, a stage generally named now *Cenomanian*, which is overlaid by the *Thuronian*, the *Upper Quader*, and this by the *Planer* of Reuss, now the *Senonian*.*

This relation of our Dakota Group flora with that of Moletin had been remarked already by the presence, in both formations, of *Sequoia fastigiata*, *Sequoia Reichenbachi*, *Gleichenia Kurriana*, and *Pinus Quenstedti*, species described in the Annual Report of 1874. But the identification of dicotyledonous is, in regard to the age of the formation, of a more definite character than that of Ferns and Conifers. And still in the same specimens of Colorado we have other leaves apparently, though less positively, referable to species of Moletin. One of them has the same form and the same character of nervation as the fragment figured by Heer as *Myrtrophyllum Shübleri*, pl. xi, fig. 2, *loc. cit.*, which is, however, half of a leaf, whose lower and upper parts are destroyed. Others represent *Magnolia* of the same type as *M. speciosa*, Heer, and there is, besides, a cylindrical obtuse receptacle, four centimeters long, a little more than one centimeter broad or thick, covered with numerous imbricated carpels, much like the receptacles of the living *Magnolia grandifolia*, and comparable, in its unripe state, to a fruit of *Magnolia* figured by Heer, pl. viii, fig. 2, as *M. amplifolia*. Other and numerous leaves, related by their shape and nervation to *Magnolia alternans*, Heer, of the Dakota Group, are somewhat unequal at the base, attached on both sides of a pedicel, and therefore mere leaflets of compound leaves. These, and still others of a different character of nervation, with leaflets more unequal at the base, resembling large species of *Sapindus*, seem referable to *Leguminosæ*, as a large silique, like that of a *Lonchocarpus*, is seen upon the same specimens.

The most interesting new type of these Cretaceous plants is described under a new generic name, that of *Liriophyllum*, by reason of its affinity to leaves of *Liriodendron*. These leaves belong probably to two species. The largest, that of *Liriophyllum Beckwithii*, sp. nov., are square in outline, divided into two lobes on each side, measuring about 30 centimeters between the points of the lateral lobes, 20 centimeters from the top of the petiole to that of the oblique obtuse terminal lobes, which descend to near the base where the midrib is split in two, each of the branches, under an angle of division of 45°, ascending to the points of the two upper lobes. There is still a nearly basilar pair of strong secondary nerves curving backward, and passing through the middle to the point of the lateral lobes, with two other secondary nerves, one merely marginal, the other between the two pairs forming the division of the leaves; the secondary nerves are scarcely branching; the lower part of the midrib, below the slightly obtuse sinus of the middle lobes, is thick, 3 millimeters, and passes downward to a petiole of the same size, broken 2 centimeters lower than the somewhat decurving base of the leaves.

The other species as yet considered under the name of *Liriophyllum*

* Heer, Moletin Flora, p. 5.

populoides, sp. nov., has the leaves much smaller, 10 centimeters broad toward the lower part, with the same length from the top of the petiole to the point. They are largest toward the base, which is nearly truncate or merely inclined to the petiole, gradually narrowed toward the obtuse point, where they are cut into two terminal lobes by a narrowly oval division, descending to the half of the laminæ or lower, where they are united in an obtuse sinus. The two upper secondary nerves pass on both sides under it, and become effaced by branching near the upper borders. In this species, all the secondary nerves—three or four pairs, according to the size of the leaves—are camptodrome, curving along the border, and effaced, as in leaves of *Populus*. The petiole is long, 3 to 3½ centimeters, flattened, and enlarged at its base. Though related by their medial division to those of *Liriophyllum Beckwithii*, these leaves have not so close an affinity to them that they may be considered as the same species.

The characters of these two species are not comparable to those of any of the present flora, to my knowledge at least. They represent an original Cretaceous type, which is found also represented in a different manner by a species of Moletin *Chondrophyllum grandidentatum*, Heer, *Ettingshausenia grandidentata*, Stiehler, whose leaves are narrowly cuneiform to the petiole, enlarging upward, and split from the top to below the middle by a split in acute angle of the midrib, which forms the borders.

Another Cretaceous type represented by the leaves from Mr. Beckwith, and worth remarking upon, is a branch of *Sequoia*, with leaves as large as those of *S. longifolia*, Lesqx., Tert. Flora, p. 79, pl. vii, fig. 14; also somewhat similar in shape, but largest in the middle, 5 millimeters broad, and gradually narrowed to the decurrent base 1 to 1½ millimeters. The branch is narrow, only 1½ millimeters thick, and does not show any scar of leaves. This species has also an affinity, though more distant, to *Sequoia Smittii*, Heer, of the Greenland Lower Cretaceous flora.

TERTIARY.

Of the Eocene specimens communicated by Rev. Lakes, I have remarked already in the Tert. Flora, p. 53, on a beautiful, well-preserved leaflet of *Pteris erosa*, on one part of a splendid pinna of *Osmunda affinis*, p. 60, and on numerous specimens of a *Myrica*, intermediate between *M. insignis* and *M. Lessigii*, p. 136. In the collections of the same contributor there is a number of specimens of pinnæ or leaflets of a peculiar Palm, whose relation to any living species is as yet unascertained. These leaflets are oval, pointed, largest in the middle, narrowed in the same degree to the acute point and to the base, averaging 17 centimeters in length and 6 centimeters wide in the middle, sharply plaited and carinate, like *Sabal* leaves. The rays converging to the base and to the point have each of their faces distinctly nerved with three primary nerves and four secondary, thinner, intermediate ones. The relative position of the leaflets to the rachis is not ascertained; they are all detached, mostly fragments. By their forms, they may be compared to those of a *Desmoncus*, like *D. macrocanthus*, Mart.; but, plaited and carinate as they are, this relation of form merely cannot be considered.

I have also mentioned in the Tertiary Flora some specimens communicated by Prof. W. A. Brownell, and described one of the leaves as *Fraxinus Brownellii*, p. 230. This year, from numerous specimens received from the same locality, I am able to complete a diagnosis rendered somewhat uncertain by the peculiar form of the leaflet, the only one which I had

for my description, and which I rightly supposed to have been deformed by compression or maceration. These leaflets are narrowed into an acumen, either long and slightly scythe-shaped, or short and straight.

This brings me to the essential contribution of this year, which is mostly from the same locality—Florissant, Colo.—indicated by some contributors as South Park, by others as Castello's Ranch, and thus marked upon the habitat of the plants of the Tertiary Flora, as if all these places were distant or separate localities. The specimens from Florissant number about five thousand. I can only give now a short and superficial account of the species which they represent.

Their examination suggests at the outset some general remarks in regard to the distribution of the vegetable remains preserved in this formation, first by the total absence of certain types, then by the predominance of others. This local flora has not any leaves or even fragments of leaves of Palms. Standing fossil trees are seen in the same locality. In the specimens of silicified wood broken from the stumps, I do not find any Palm wood. I have been informed, however, that trees of this kind had been remarked there formerly, but had been totally broken and taken away as curiosities by the numerous visitors of the locality. I have been unable to ascertain the truth of that assertion. The characters of the leaves refer them mostly to plants of a moderate climate, and, as I have remarked in the Tertiary flora, to species of mountains or of high valleys. Of the other division of the monocotyledonous also, there are scarcely any remains. The *Glumaceæ* only have two fragments of leaves of *Phragmites*. From the lower orders of plants we find there merely a few leaflets of Ferns, two specimens of a *Chara* and *Salvinia Alleni*, Lesqx.; this represented by a comparatively large number of well-preserved specimens, whose characters slightly modified do not present even sufficient differences for authorizing a separation in varieties. Still more remarkable is the absence of fruits in the shales of Florissant, which in its compounds has preserved the most delicate organisms, feathers, insects, small flies, petals, even anthers and stamens of flowers, but no hard fruits of any kind.

The preponderance of remains of other species is not the less remarkable, and perplexes the paleontologist who is trying to understand the cause of that heaping of materials at Florissant, and the way and action which has brought them there. For example, the leaves of *Planera longifolia*, and of its varieties, which appear to represent also *Planera Ungeri*, and perhaps another species of the same genus, constitute there about one-half of the preserved vegetable remains. We have at least two thousand specimens of these leaves. Have they been brought by mountain rivulets or torrents into a lake? We should then find the fruits as well as the leaves, and the action of transfer seems scarcely probable in considering the very delicate texture of other organisms preserved. Have the plants grown around the basin of water? The objection is the same on account of the absence of fruits and of the very fragmentary state of the remains of Conifers, which, for *Glyptostrobus* at least, are branches, leaves, and small cones, abundant enough, but all ground as if they had been for a long time exposed to the movement of water or to atmospheric influences. The presence of remains of flowers, of unripe carpels of *Ulmus*, *Acer*, etc., would imply a deposition of vegetable materials in spring time, before the maturity of the seeds; and then to account for the absence of fruits, we should have to suppose a gradual drying up of the lake or swamp during the summer. In that case, as the broken fragments of Conifers indicate a prolonged atmospheric action by their decomposition, it would be possible to suppose the decomposition

of the fruits also. This hypothesis seems confirmed by the presence of well-preserved branches of *Taxodium distichum miocenicum*, Heer, as from the living *Taxodium*, it is seen that the fragments are mostly detached and thrown upon the ground in winter time or early in the spring.

After the *Planera* leaves, those which are the most abundant in the collection of Florissant are those of *Myrica*, two species, especially *Myrica acuminata*, Ung., as represented in Tert. Flora, pl. xvii, figs. 1–4, a form somewhat different from that of Europe, and which seem referable to two species of the Gypses of Aix, *Myrica arguta*, Heer, and *M. Zachariensis*, Sap.; the other, *M. Ludwigii*, Schp., a fragment of which is figured in Tert. Flora, pl. lxv, fig. 9. Other species of the same genus are there also in a few specimens, especially *Myrica latiloba*, Heer, var. *acutiloba*, same type as that of the Tert. Flora, pl. xvii, fig.13. The leaflets of the species which is described in the same volume, p. 246, pl. xliii, figs. 2–4, as *Callicoma microphylla*, Ett., are as plentiful in the collection as those of *Myrica*—perhaps more. Some are attached to branches, and in their positions are alternate, distant, the upper basilar side broader and rounded, the lower narrow, a disposition at variance with that of the leaves of *Myrica* and of *Rhus*, the only genera of our flora to which they might have been referred in their separate state. And as *Callicoma* has in its species the leaves opposite, this reference is still less admissible, though from our specimen it is not possible to doubt the identity of the leaves with those described by the German author under this name. I am unable as yet to decide upon the true reference of these leaves, which, except the craspedodrome nervation, have a great affinity to those of *Myrica Saportana*, Schp. They are variable in size; some of them, the upper ones, are very narrow, 4 millimeters at the base, while others measure more than one centimeter. The length does not differ comparatively to the width. Their form and disposition are like those of *Sapindus* or of *Zanthoxylon*.

Briefly reviewing the plants of Florissant, in regard to the botanical series to which they belong, I find a large number of the *Amentaceæ* in the following genera:—*Carpinus*, two species, one referable to *C. pyramidalis*, Heer, the other to *C. grandis*, Ung. *Ulmus* has a species of the most common type of the Miocene, *U. Braunii*, Heer, and another, referable to *U. Fischeri*, Heer. *Betula* and *Alnus* are as yet indistinctly recognized; two leaves seem referable to *B. Dryadum*, Brgt. Of *Celtis*, there are leaves with entire and others with slightly dentate borders, which have a great affinity to the present *C. occidentalis*, and its variety *C. integrifolia*, Nutt. They may, however, represent two species. *Corylus* and *Fagus* are absent. I can also scarcely separate as yet leaves positively referable to *Quercus*. *Populus* has four species: one, *P. latior*, a small leaf like the one represented by Heer as var. *denticulata*; two other distinct new species, one of the section of *P. glandulifera*, with smaller, more acuminate leaves, without basilar glands; the other, represented by two leaves still smaller, thin, or not coriaceous, 1½ centimeters broad, and as long, entire, with the base truncato-cordate, rapidly narrowing to a point, borne upon petioles about as long as the leaves, slightly inflated at the point of connection to the lamina, lateral primary nerves diverging at a broad angle, and secondary veins only two pairs, parallel, and very thin.

A fourth species is represented by a large number of leaves, remarkably different, in their size especially. They vary from 4½ to 23 centimeters long, and from 1 to 8 centimeters broad near the base, where they are generally the largest, and there always rounded to a long,

broad, flat petiole. Their form is either oblong, acuminate or lanceolate, narrowing to a long acumen. The primary basilar nerves, one or two pairs, are on a more acute angle of divergence than the secondary, passing high up along the borders in successive curves or festoons joined to the lower secondary veins by strong nervilles. The middle vein is thick and flat. This species is allied to *Ficus populina*, Heer, from which it differs essentially by narrower leaves, rounded to the petiole, and by the ultimate areolation not punctulate; and still more closely related to *Quercus Heerii*, Sap., Et., 1, 1, p. 87, pl. vii, fig. 3 A, which seems to represent the same species in one of its smaller leaves. The only difference remarked in the American specimens is the broader flat petiole, which rather resembles that of a *Ficus*, but the form of the leaves, the nervation and areolation, the divisions of the obtusely crenate borders are exactly similar. The French author has found involucres of seeds of *Populus* with his species, and figures, as point of comparison, *Populus laurifolia*, Ledb., a living species of Siberia, which has about the same character; hence the reference of these leaves to this genus seems authorized. This species, he says, is extremely rare in the Gypses of Aix. Of *Salix*, the collection of Florissant has a number of leaves identified with *S. lavateri*, Heer, *S. integra*, Al. Br., *S. media*, Al. Br., and *S. varians*, Goepp. *Platanus*, *Liquidambar*, *Ficus*, and all the *Laurineæ*, are mostly absent. Indeed, there are scarcely any coriaceous leaves among the specimens, and none of large size except the *Populus* mentioned above. *Fraxinus* is represented by three species, one of them, *F. Brownellii*, described in Flor. Tert., *loc. cit.* There is no *Diospyros*, but two or three species of the *Ericaceæ;* one *Andromeda*, perhaps two; one *Vaccinium;* and in the *Araliaceæ* one leaf only. Of *Vitis*, *Cornus*, *Magnolia*, *Nelumbium*, of the *Tiliaceæ*, also there is none. *Acer* has one species; one leaf only of the type of *A. pseudo-campestre*, Heer, and fruits still smaller than those of *Acer decipiens*, Heer, as figured in Fl. Tert. Helv., pl. cxvii, fig. 22. *Per contra*, the *Sapindaceæ* are very abundant; there are numerous specimens of *S. stellariæfolius* and *S. angustifolius* of the Tert. Flora, pl. xlix, with still two or three other species, and in the *Frangulaceæ*, leaves of *Staphylea*, not as well preserved as that already figured, *loc. cit.*, pl. xlviii, a few leaves of *Celastrus*, and two species of *Ilex*. The *Rhamneæ* and the *Juglandeæ* have not any specimen in the collection, while the *Anacardiaceæ* are most abundant in not less than six or seven species of *Rhus* and one of *Pistacia*. The *Rosaceæ* have a *Prunus* and species of *Spirea* and very finely preserved leaves of an *Amelanchier*, which are scarcely distinguishable from some of the varieties of the living species. This, with a large number of *Leguminosæ* of the genera *Colutea*, *Robinia*, and *Cassia*, constitutes the more essential part of the specimens as far as I have been able to fix a determination in sorting them for future examination. The flowers, petals, sepals, stamens, and pistils, though not very numerous, are interesting. Flowers of *Acer* are the only ones which I could recognize at first sight. Of other plants of undetermined relation, there is *Trilobium* of Unger. As many specimens are obscure, this collection will demand a great deal of work and research for the final determination of the species.

Professor Scudder has sent with the above, from near Randolph, Wyo., a small number of very fine, admirably preserved specimens, regrettably too few in number. They represent one *Flabellaria*, with the petiole truncate at the point of union to the rays, narrowly and equally nerved, the rays numerous and narrow, disposed like those of *F. Eocenica*, Lesqx., Tert. Flora, pl. xiii, fig. 1, but more coarsely nerved, at least for the primary nerves, the intermediate veins being less numerous and scarcely observ-

able; *Ficus Lynx*, Ung., a *Liquidambar* slightly distinct from *L. Europeum* by its lobes oblong and nearly obtuse, rather than acuminate. As there is one leaf only, this difference cannot be positively ascertained as specific; a leaf of large size, apparently a *Tilia; Cinnamomum Scheuchzeri;* the half of another very large leaf, a *Quercus*, related by its dentate borders and its size to *Q. Moorii*, Lesqx., but differing by the lateral nerves more open, nearly in right angle to the midrib, and more arched; a *Diospyros*, a *Phragmites*, and a leaf of *Acer*, remarkably similar to those figured and described by Massalongo as *Liquidambar Scarabellianum*, apparently a variety of *Acer Trilobatum;* one species of *Rhus;* a *Myrica*, of the type of *M. speciosa*, Ung.; a fine *Zizyphus*, allied to *Z. tiliæfolius*, but differing by a long petiole and other less marked characters; seeds of *Ailanthus;* leaves of a *Laurus;* and petaloidal involucres not yet determined.

This review is, of course, a superficial one. It gives only an insight into the general characters of the two vegetable groups represented by the specimens, the first referable to the Upper Miocene, the other apparently to the Eocene. It will serve as an introduction to the list of the Cretaceous and Tertiary plants described until now from the American formations, and which may be used as a point of departure for future researches and publications on the subject.

PART II.—CATALOGUE OF THE CRETACEOUS AND TERTIARY PLANTS OF NORTH AMERICA, WITH REFERENCES TO THE DESCRIPTIONS.

EXPLANATION OF ABBREVIATIONS USED IN THE CATALOGUE.

Am. Journ. Sci. & Arts.—American Journal Sciences and Arts, vol. xxvii, No. 81, May, 1859.

Annual Reports.—Annual Reports of the U. S. Geological and Geographical Survey of the Territories, 1869 to 1874.

Boston Journ. of Nat. Hist.—Boston Journal of Natural History, 1863.

Cret. Flora.—Report of the U. S. Geological Survey of the Territories by F. V. Hayden. Vol. vi. Cretaceous Flora. By L. Lesquereux. (1874.)

B. N. Amer. B. Comm.—Report on the Geology and Resources of the Region in the Vicinity of the Forty-ninth Parallel. By George Mercer Dawson. (1875.)

Ext. Floras.—Notes on the Later Extinct Floras of North America, with descriptions of some new species of fossil plants from the Cretaceous and Tertiary strata. By J. S. Newberry. 1868.

Foss. Plants of Vancouver.—Ueber einige fossile Pflanzen von Vancouver und British-Columbien. By Oswald Heer.

Flora Alask.—Flora Fossilis Alaskana. By Oswald Heer. 1869.

Geol. of Vermont.—Report on the Geology of Vermont. By Prof. Ed. Hitchcock. (1861.)

Geol. of Tenn.—Geology of Tennessee. By Prof. James M. Safford. (1869.)

Phyll. du Néb.—Les Phyllites Crétacées du Nébraska. Par MM. les Prof. J. Capellini et O. Heer. (1866.)

Tert. Flora.—Report of the U. S. Geological Survey of the Territories, vol. vii. F. V. Hayden. Tertiary Flora. By L. Lesquereux. (1878.)

Trans. Am. Phil. Soc.—Transactions of the American Philosophical Society of Philadelphia, vol. xiii, (1863). (?)

Whitney's Geol. of the Aurif. Dep.—Report on the Fossil Plants of the Auriferous Gravel Deposits of the Sierra Nevada. By L. Lesquereux. In Prof. F. D. Whitney's Memoirs of the Museum of Comparative Zoölogy at Harvard College, vol. vi, no. 2, (1878).

CRETACEOUS.

CRYPTOGAMÆ.

THALLOPHYTES.

Zonarites, Brgt.

1. *Zonarites digitatus*, Brgt., Lesqx., Cret. Flora, p. 44, pl. i, fig. 1.

FILICES.

Lygodium, Sw.

2. *Lygodium trichomanoides*, Lesqx., Cret. Flora, p. 45, pl. i, fig. 2.

Hymenophyllum, Sw.

3. *Hymenophyllum cretaceum*, Lesqx., Cret. Flora, p. 45, pl. i, figs. 3, 4; pl. xxix, fig. 6.

Sphenopteris, Brgt.

4. *Sphenopteris corrugata*, Newby., Ext. Floras, p. 10, pl. ii, fig. 6.

Pecopteris, Brgt.

5. *Pecopteris Nebraskana*, Heer, Lesqx., Cret. Flora, p. 46, pl. xxix, f. 5.

Gleichenia, Nutt.

6. *Gleichenia Kurriana*, Heer, Lesqx., Cret. Flora, p. 47, pl. i, figs. 5–5 *c*.
7. *Gleichenia Nordenskioldi ?*, Heer, Lesqx., Ann. Rep., p. 334, pl. ii, fig. 5.

PHENOGAMÆ.

CYCADEÆ.

Pterophyllum, Brgt.

8. *Pterophyllum ? Haydenii*, Lesqx., Cret. Flora, p. 49, pl, i, figs, 6, 6 *b*.

CONIFERÆ.

Abietites, Endl.

9. *Abietites Ernestinæ*, Lesqx., Cret. Flora, p. 49. pl. i, fig. 7.

Araucaria, Juss.

10. *Araucaria spatulata*, Newby., Ext. Floras, p. 10, pl. ii, figs. 5, 5 *a*.

Sequoia, Endl.

11. *Sequoia formosa*, Lesqx., Cret. Flora, p. 50, pl. i, figs. 9, 9 *b*.
12. *Sequoia Reichenbachi ?*, Heer, Lesqx., Cret. Flora, p. 51, pl. i, f. 10–10 *b*.
13. *Sequoia fastigiata ?*, Sternb., Lesqx., Ann. Report, 1874, p. 335, pl. iii, figs. 2, 8, 8 *a*.
14. *Sequoia condita*, Lesqx., Ann. Report, 1874, p. 335, pl. iv, figs. 5–7.

Pinus, Linn.

15. *Pinus Quenstedti*, Heer, Lesqx., Ann. Rep., 1874, p. 336, pl. iii, figs. 6, 7.

Glyptostrobus, Endl.

16. *Glyptostrobus gracillimus*, Lesqx., Cret. Flora, p. 52, pl. i, figs. 8, 11–11 *f*.

Inolepis, Heer.

17. *Inolepis?* species, Lesqx., Ann. Report, 1874, p. 337, pl. iv, fig. 8.

Phyllocladus, Rich.

18. *Phyllocladus subintegrifolius*, Lesqx., Cret. Flora, p. 54, pl. i, fig. 12; Ann. Report, 1874, p. 337, pl. ii, fig. 4.

MONOCOTYLEDONES.

Glumaceæ.

Phragmites, Adans.

19. *Phragmites cretaceus*, Lesqx., Cret. Flora, p. 55, pl. i, figs. 13, 14; pl. xxix, fig. 7.

Dioscoreæ.

Dioscorea, Plum.

20. *Dioscorea? cretacea*, Lesqx., Cret. Flora, p. 56, pl. xxviii, fig. 10.

Palmæ.

Flabellaria, St.

21. *Flabellaria? minima*, Lesqx., Cret. Flora, p. 56, pl. xxx, fig. 12; pl. xxvi, fig. 2.

DICOTYLEDONES.

Amentaceæ.

Myrica, Linn.

22. *Myrica obtusa*, Lesqx., Cret. Flora, p. 63, pl. xxix, fig. 10.
23. *Myrica cretacea*, Lesqx., Ann. Report, 1874, p. 339, pl. iii, fig. 4.
24. *Myrica semina*, Cret. Flora, p. 63, pl. xxvii, figs. 4, 4 *a*.

Betula, Tourn.

25. *Betula Beatriciana*, Lesqx., Cret. Flora, p. 61, pl. v, fig. 5; pl. xxx, fig. 4.

Betulites, Goepp.

26. *Betulites denticulata*, Heer, Phyll. du Néb., p. 15, pl. iv, figs. 5, 6.

Alnites, Goepp.

27. *Alnites grandifolia*, Newby., Ext. Floras, p. 9, pl. iv, fig. 2.

Fagus, Tourn.

28. *Fagus polyclada*, Lesqx., Cret. Flora, p. 67, pl. v, fig. 6.
29. *Fagus cretacea*, Newby., Ext. Floras, p. 23, pl. ii, fig. 3.

Dryophyllum, Deb.

30. *Dryophyllum* (*Quercus*) *latifolium*, Lesqx., Ann. Report, 1874, p. 340, pl. vi, fig. 1.
31. *Dryophyllum* (*Quercus*) *primordiale*, Lesqx., Cret. Flora, p. 64, pl. v, fig. 7.
32. *Dryophyllum* (*Quercus*) *salicifolium*, Lesqx., Ann. Report, 1874, p. 340, pl. viii, fig. 2.

Quercus, Linn.

33. *Quercus hexagona*, Lesqx., Cret. Flora, p. 64, pl. v, fig. 8.
34. *Quercus? Ellsworthiana*, Lesqx., Cret. Flora, p. 65, pl. vi, fig. 7.
35. *Quercus? poranoides*, Lesqx., Cret. Flora, p. 66, pl. xxx, fig. 9.
36. *Quercus salicifolia*, Newby., Ext. Floras, p. 24, pl. ii, fig. 4.
37. *Quercus cuneata*, Newby., Ext. Floras, p. 25.
38. *Quercus antiqua*, Newby., Ext. Floras, p. 26.
39. *Quercus sinuata*, Newby., Ext. Floras, p. 27.

Salix, Tourn.

40. *Salix nervillosa*, Heer, Phyll. du Néb., p. 15, pl. i, fig. 3.
41. *Salix proteæfolia*, Lesqx., Cret. Flora, p. 60, pl. v, figs. 1–4.
42. *Salix membranacea*, Newby., Ext. Floras, p. 19, pl. i, figs. 5, 8.
43. *Salix Meekii*, Newby., Ext. Floras, p. 19, pl. i, fig. 1.
44. *Salix flexuosa*, Newby., Ext. Floras, p. 21, pl. i, fig. 4.
45. *Salix cuneata*, Newby., Ext. Floras, p. 21, pl. i, figs. 2, 3.

Populus, Tourn.

46. *Populus litigosa*, Heer, Phyll. du Néb., p. 13, pl. i, fig. 2.—Newby., Ext. Floras, pl. iii, fig. 6; pl. iv, fig. 1.
47. *Populus cyclophylla*, Heer, Acad. Nat. Sci. Phila., 1858, p. 266.—Newby., Ext. Floras, pl. iii, figs. 3, 4.
48. *Populus elliptica*, Newby., Ext. Floras, p. 16, pl. iii, figs. 1, 2.
49. *Populus microphylla*, Newby., Ext. Floras, p. 17, pl. iii, fig. 5.
50. *Populus ? cordifolia*, Newby., Ext. Floras, p. 18, pl. iii, fig. 7; pl. v, fig. 5.

Populites, Lesqx.

51. *Populites Lancastriensis*, Lesqx., Cret. Flora, p. 58, pl. iii, fig. 1.
52. *Populites elegans*, Lesqx., Cret. Flora, p. 59, pl. iii, fig. 3.

Platanus, Linn.

53. *Platanus ? Newberriana*, Heer, Phyll. du Néb., p. 16, pl. 1, fig. 4.
54. *Platanus obtusiloba*, Lesqx., Cret. Flora, p. 69, pl. vii, figs. 3, 4.
55. *Platanus primæva*, Lesqx., Cret. Flora, p. 69, pl. vii, fig. 2; pl. xxvi, fig. 2.
56. *Platanus Heerii*, Lesqx., Cret. Flora, p. 70, pl. viii, fig. 4; pl. ix, figs. 1, 2.
57. *Platanus diminutiva*, Lesqx., Cret. Flora, p. 73, pl. viii, fig. 5.
58. *Platanus latiloba*, Newby., Ext. Floras, p. 23, pl. ii, fig. 4.

Liquidambar, Linn.

59. *Liquidambar integrifolium*, Lesqx., Cret. Flora, p. 56, pl. ii, figs. 1, 3; pl. xxiv, fig. 2; pl. xxix, fig. 8.

URTICINEÆ.

Ficus, Tourn.

60. *Ficus primordialis*, Heer, Phyll. du Néb., p. 16, pl. iii, fig. 1.
61. *Ficus Halliana*, Lesqx., Cret. Flora, p. 68, pl. xxviii, figs. 3, 9.
62. *Ficus laurophyllum*, Lesqx., Ann. Report, 1874, p. 342, pl. v, fig. 7.

PROTEACEÆ.

Lomatia, R. Br.

63. *Lomatia ? Saportanea*, Lesqx., Ann. Report, 1874, p. 346, pl. vi, fig. 2.—*Todea ? Saportanea*, Lesqx., Cret. Flora, p. 48, pl. xxix, figs. 1–4.

Proteoides, Heer.

64. *Proteoides daphnogenoides*, Heer, Phyll. du Néb., p. 17, pl. iv, figs. 9, 10.—Lesqx., Cret. Flora, p. 85, pl. xv, figs. 1, 2.
65. *Proteoides acuta*, Heer, Phyll. du Néb., p. 17, pl. iv, figs. 7, 8.—Lesqx., Cret. Flora, p. 86, pl. xv, fig. 3; pl. xxviii, fig. 13.
66. *Proteoides Grevilleæformis*, Heer, Phyll. du Néb., p. 17, pl. iv, fig. 11.—Lesqx., Cret. Flora, p. 86, pl. xxviii, fig. 12.
66 *a*. *Embothrites daphneoides*, Lesqx., Cret. Flora, p. 87, pl. xxx, fig. 10.

LAURINEÆ.

Laurus, Linn.

67. *Laurus Nebrascensis*, Lesqx., Cret. Flora, p. 74, pl. x, fig. 1; pl. xxviii, fig. 14.
68. *Laurus macrocarpa*, Lesqx., Cret. Flora, p. 74, pl. x, fig. 2.
69. *Laurus proteæfolia*, Lesqx., Ann. Rep., 1874, p. 342, pl. v, figs. 1, 2.

Persea, Gaertn.

70. *Persea Leconteana*, Lesqx., Cret. Flora, p. 75, pl. xxviii, fig. 1.
71. *Persea Sternbergii*, Lesqx., Cret. Flora, p. 76, pl. vii, fig. 1.

Daphnogene, Ung.

72. *Daphnogene cretacea*, Lesqx., Ann. Rep., 1874, p. 343.

Cinnamomum, Burm.

73. *Cinnamomum Scheuchzeri ?*, Heer, Lesqx., Cret. Flora, p. 83, pl. xxx, figs. 2, 3.
74. *Cinnamomum Heerii*, Lesqx., Cret. Flora, p. 84, pl. xxviii, fig. 5.

Oreodaphne, Nees.

75. *Oreodaphne cretacea*, Lesqx., Cret. Flora, p. 84, pl. xxx, fig. 5.

Sassafras, Nees.

76. *Sassafras Mudgei*, Lesqx., Cret. Flora, p. 78, pl. xiv, figs. 3, 4; pl. xxx, fig. 7.
77. *Sassafras acutilobum*, Lesqx., Cret. Flora, p. 79, pl. xiv, figs. 1, 2.
78. *Sassafras cretaceum*, Newby., Ext. Floras, p. 14, pl. vi, figs. 1–4.—*Sassafras* (*Araliopsis*) *cretaceum*, Lesqx., Cret. Flora, p. 80, pl. xii, fig. 2.—Var. *dentatum*, Lesqx., Cret. Flora, pl. xi, figs. 1, 2.
79. *Sassafras* (*Araliopsis*) *cretaceum obtusum*, Lesqx., Cret. Flora, p. 80, pl. xii, fig. 3; pl. xiii, fig. 1.
80. *Sassafras* (*Araliopsis*) *mirabile*, Lesqx., Cret. Flora, p. 80, pl. xii, fig. 1.
81. *Sassafras* (*Araliopsis*) *recurvata*, Lesqx., Ann. Rep., 1874, p. 345.—*Platanus recurvata*, Lesqx., Cret. Flora, p. 71, pl. x, figs. 3–5.

ASARINEÆ.

Aristolochites, Heer.

82. *Aristolochites dentata*, Heer, Phyll. du Néb., p. 18, pl. ii, figs. 1, 2; Cret. Flora, p. 87, pl. xxx, fig. 6.

GAMOPETALEÆ.

DIOSPYRINEÆ.

Sapotacites, Ett.

83. *Sapotacites Haydenii*, Heer, Newby., Ext. Floras, p. 8. pl. v, fig. 1.

Diospyros, Linn.

84. *Diospyros primæva*, Heer, Phyll. du Néb., p. 19, pl. i, figs. 6, 7.
85. *Diospyros rotundifolia*, Lesqx., Cret. Flora, p. 89, pl. xxx, fig. 1.
86. *Diospyros ambigua*, Lesqx., Cret. Flora, p. 89, pl. vi, fig. 6.
87. *Diospyros ?* species, Newby., Ex. Floras, pl. iii, fig. 8.

ERICACEÆ.

Andromeda, Linn.

88. *Andromeda Parlatorii*, Heer, Phyll. du Néb., p. 18, pl. i, fig. 5; Lesqx., Cret. Flora, p. 88, pl. xxiii, figs. 6, 7; pl. xxviii, fig. 15.
89. *Andromeda affinis*, Lesqx., Ann. Report, 1874, p. 348, pl. iii, fig. 5.

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DISCANTHEÆ.

Aralia, Linn.

90. *Aralia imperfecta*, Lesqx.; *Aralia tripartita*, Lesqx., Ann. Report, p. 348, pl. 1, fig. 1.*
91. *Aralia concreta*, Lesqx., Ann. Report, p. 349, pl. iv, figs. 2, 3, 4.—*Liquidambar integrifolium*, Lesqx., Cret. Flora, p. 57, pl. xxix, fig. 8.

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* *Aralia tripartita* is preoccupied by Saporta.

92. *Aralia Towneri*, Lesqx., Ann. Report, 1874, p. 349, pl. iv, fig. 1.
93. *Aralia quinquepartita*, Lesqx., Cret. Flora, p. 90, pl. xv, fig. 6.
94. *Aralia Saportanea*, Lesqx., Ann. Report, p. 350, pl. i, figs. 2, 2 *a*.

Hedera, Linn.

95. *Hedera ovalis*, Lesqx., Cret. Flora, p. 91, pl. xxv, fig. 3, and pl. xxvi, fig. 4.
96. *Hedera Schimperi*, Lesqx., Ann. Report, 1874, p. 351, pl. vii, fig. 5.
97. *Hedera platanoidea*, Lesqx., Ann. Report, 1874, p. 351, pl. iii, fig. 3.

Cissites, Heer.

98. *Cissites insignis*, Heer, Phyll. du Néb., p. 19, pl. ii, figs. 3, 4.
99. *Cissites Harkerianus*, Lesqx., Ann. Report, 1874, p. 352, pl. vii, figs. 1, 2.
100. *Cissites affinis*, Lesqx., Ann. Report, 1874, p. 352.—*Platanus affinis*, Lesqx., Cret. Flora, p. 71, pl. iv, fig. 4; pl. xi, fig. 3.
101. *Cissites acuminatus*, Lesqx., Ann. Report, 1874, p. 353, pl. viii, fig. 1.
102. *Cissites Heerii*, Lesqx., Ann Report, 1874, p. 353, pl. vi, fig. 3.
103. *Cissites cyclophylla*, Lesqx., Ann. Report, 1874, p. 353.—*Populites cyclophylla ?*, Heer, Lesqx., Cret. Flora, p. 59, pl. iv, fig. 5, and pl. xxiv, fig. 4.
104. *Cissites obtusus*, Lesqx., Ann. Report, 1874, p. 354.—*Sassafras obtusus*, Lesqx., Cret. Flora, p. 81, pl. xiii, figs. 2, 4.

Ampelophyllum, Lesqx.

105. *Ampelophyllum attenuatum*, Lesqx., Ann. Report, 1874, p. 354, pl. ii, fig. 3.
106. *Ampelophyllum ovatum*, Lesqx., Ann. Report, 1874, p. 355.—*Celtis ? ovata*, Lesqx., Cret. Flora, p. 66, pl. iv, figs. 2, 3.

Hamamelites, Sap.

107. *Hamamelites Kansaseana*, Lesqx., Ann. Report, 1874, p. 355, pl. vii, fig. 4.—*Alnus Kansaseana*, Lesqx., Cret. Flora, p. 62, pl. xxx, fig. 8.
108. *Hamamelites quadrangularis*, Lesqx., Ann. Report, 1874, p. 355.—*Alnites quadrangularis*, Lesqx., Cret. Flora, p. 62, pl. iv, fig. 1.

POLYCARPICÆ.

Magnolia, Linn.

109. *Magnolia tenuifolia*, Lesqx., Cret. Flora, p. 92, pl. xxi, fig. 1.
110. *Magnolia alternans*, Heer, Phyll. du Néb., p. 20, pl. iii, figs. 2, 3, 4; pl. iv, figs. 1, 2.—Lesqx., Cret. Flora, p. 92, pl. xviii, fig. 4.—Newby., Ext. Floras, pl. v, fig. 6.
111. *Magnolia Capellini*, Heer, Phyll. du Néb., p. 21, pl. iii, figs. 5, 6.—Lesqx., Ann. Report, 1874, p. 356.
112. *Magnolia obovata*, Newby., Ext. Floras, p. 15, pl. ii, fig. 2; pl. iv, fig. 4.

Liriodendron, Linn.

113. *Liriodendron Meekii*, Heer, Phyll. du Néb., p. 21, pl. iv, figs. 3. 4.—Newby., Ext. Floras, p. 8, pl. vi, figs. 5, 6.

114. *Liriodendron primævum*, Newby., Ext. Floras, p. 12, pl. vi, fig. 7.
115. *Liriodendron intermedium*, Lesqx., Cret. Flora, p. 93, pl. xx, fig. 5.
116. *Liriodendron giganteum*, Lesqx., Cret. Flora, p. 93, pl. xxii, fig. 2.

Menispermites, Lesqx.

117. *Menispermites obtusilobus*, Lesqx., Cret. Flora, p. 94, pl. xxv, figs. 1, 2; pl. xxvi, fig. 3; Ann. Report, 1874, p. 356, pl. vii, fig. 3.
118. *Menispermites saliniensis*, Lesqx., Cret. Flora, p. 95, pl. xx, figs. 1, 4.
119. *Menispermites acerifolius*, Lesqx., Cret. Flora, p. 96, pl. xx, figs. 2, 3.
120. *Menispermites populifolius*, Lesqx., Ann. Rep., 1874, p. 357, pl. v, fig. 3.
121. *Menispermites ovalis*, Lesqx., Ann. Report, 1874, p. 357, pl. v, fig. 4.
122. *Menispermites cyclophyllus*, Lesqx., Ann. Rep., 1874, p. 358, pl. vi, fig. 4.

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Sterculia, Linn.

123. *Sterculia lineariloba*, Lesqx., Ann. Report, 1874, p. 358.

Grewiopsis, Sap.

124. *Grewiopsis Haydenii*, Lesqx., Cret. Flora, p. 97, pl. iii, figs. 2, 4; pl. xxiv, fig. 3.

ACERINEÆ.

Acerites, Mass.

125. *Acerites pristinus*, Newby., Ext. Floras, p. 15, pl. v, fig. 4.

Negundoides, Lesqx.

126. *Negundoides acutifolius*, Lesqx., Cret. Flora, p. 97, pl. xxi, fig. 5.

FRANGULINEÆ.

Celastrophyllum, Ett.

127. *Celastrophyllum ensifolium*, Lesqx., Cret. Flora, p. 108, pl. xxi, figs. 2, 3.

Ilex, Linn.

128. *Ilex strangulata*, Lesqx., Ann. Report, 1874, p. 359, pl. viii, fig. 3.

Paliurus, Tourn.

129. *Paliurus membranaceus*, Lesqx., Cret. Flora, p. 108, pl. xx, fig. 6.

Rhamnus, Linn.

129 *bis*. *Rhamnus tenax*, Lesqx., Cret. Flora, p. 109, pl. xxi, fig. 4.

TEREBINTHINEÆ.

Juglans, Linn.

130. *Juglans? Debeyana*, Heer, Lesqx., Cret. Flora, p. 110, pl. xxiii, figs. 1–5.—*Populus? Debeyana*, Heer, Phyll. du Néb., p. 14, pl. i, fig. 1.—Newby., Ext. Floras, p. 17, pl. iv, fig. 3.

Phyllites, St.

131. *Phyllites rhoifolius*, Lesqx., Cret. Flora, p. 111, pl. xxii, figs. 5, 6.

ROSIFLOREÆ.

Prunus, Linn.

132. *Prunus? cretacea*, Lesqx., Cret. Flora, p. 111, pl. xxiii, figs. 8, 9; Ann. Report, 1874, p. 361, pl. iv, fig. 9.

Pyrus, Lind.

133. *Pyrus cretacea*, Newby., Ext. Floras, p. 12, pl. ii, fig. 7.

LEGUMINOSÆ.

Leguminosites, Br.

134. *Leguminosites Marcouanus*, Heer, Newby., Ext. Floras, p. 8, pl. v, fig. 2.

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Aspidiophyllum, Lesqx.

135. *Aspidiophyllum trilobatum*, Lesqx., Ann. Report, 1874, p. 361, pl. ii, figs. 1, 2.

Protophyllum, Lesqx.

136. *Protophyllum Sternbergii*, Lesqx., Cret. Flora, p. 101, pl. xvi; pl. xviii, fig. 2.
137. *Protophyllum Leconteanum*, Lesqx., Cret. Flora, p. 103, pl. xvii, fig. 4; pl. xxvi, fig. 1.
138. *Protophyllum? Nebrascense*, Lesqx., Cret. Flora, p. 103, pl. xxvii, fig. 3.
139. *Protophyllum quadratum*, Lesqx., Cret. Flora, p. 104, pl. xix, fig. 1.
140. *Protophyllum minus*, Lesqx., Cret. Flora, p. 104, pl. xix, fig. 2; pl. xxvii, fig. 1; Ann. Report, 1874, p. 362, pl. v, fig. 6.
141. *Protophyllum multinerve*, Lesqx., Cret. Flora, p. 105, pl. xviii, fig. 1.
142. *Protophyllum rugosum*, Lesqx., Cret. Flora, p. 105, pl. xvii, figs. 1, 2; pl. xix, fig. 3.
143. *Protophyllum Haydenii*, Lesqx., Cret. Flora, p. 106, pl. xvii, fig. 3.
144. *Protophyllum crednerioides*, Lesqx., Ann. Report, 1874, p. 363, pl. iii, fig. 1; pl. viii, fig. 4.
145. *Protophyllum? Mudgei*, Lesqx., Cret. Flora, p. 106, pl. xviii, fig. 3.

Anisophyllum, Lesqx.

146. *Anisophyllum semi-alatum*, Lesqx., Cret. Flora, p. 98, pl. vi, figs. 1–5.

Eremophyllum, Lesqx.

147. *Eremophyllum fimbriatum*, Lesqx., Cret. Flora, p. 107, pl. viii, fig. 1.

INCERTÆ AFFINITATIS.

Phyllites, St.

148. *Phyllites Vanonæ*, Heer, Phyll. du Néb., p. 22, pl. i, fig. 8.—Lesqx., Cret. Flora, p. 113, pl. xx, fig. 7; pl. xxviii, fig. 8.

149. *Phyllites obcordatus*, Newby., Ext. Floras, p. 8, pl. v, fig. 3.
150. *Phyllites betulæfolius*, Lesqx., Cret. Flora, p. 112, pl. xxviii, figs. 4, 7.
151. *Phyllites rhomboideus*, Lesqx., Cret. Flora, p. 112, pl. vi, fig. 8.
152. *Phyllites cotinus*, Lesqx., Ann. Report, 1874, p. 364.—*Bumelia Marcouana*, Heer, Lesqx., Cret. Flora, p. 90, pl. xxviii, fig. 2.
153. *Phyllites umbonatus*, Lesqx., Cret. Flora, p. 113, pl. xix, fig. 4.
154. *Phyllites amorphus*, Lesqx., Cret. Flora, p. 113, pl. xxii, figs. 3, 4.

Ptenostrobus, Lesqx.

155. *Ptenostrobus Nebrascensis*, Lesqx., Cret. Flora, p. 114, pl. xxiv, fig. 1.

Caulinites, Br.

156. *Caulinites spinosus*, Lesqx., Cret. Flora, p. 115.
157. *Carpolithes ?*, Auct., Lesqx., Cret. Flora, p. 114, pl. xxvii, fig. 5; pl. xxx, fig. 11.

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1. *Spheria lapidea*, Lesqx., Tert. Flora, p. 34, pl. i, fig. 3.
2. *Spheria myricæ*, Lesqx., Tert. Flora, p. 34, pl. i, fig. 4.
3. *Spheria rhytismoides*, Lesqx., Tert. Flora, p. 35, pl. i, figs. 5, 5 *a*.

Sclerotium, Tode.

4. *Sclerotium rubellum*, Lesqx., Tert. Flora, p. 35, pl. i, figs. 2–2 *f*.

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Opegrapha, Pers.

5. *Opegrapha antiqua*, Lesqx., Tert. Flora, p. 36, pl. i, figs. 1–1 *c*.

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6. *Halymenites striatus*, Lesqx., Tert. Flora, p. 37, pl. i, fig. 6.
7. *Halymenites major*, Lesqx., Tert. Flora, p. 38, pl. i, figs. 7, 8.
8. *Halymenites minor*, F. O., Tert. Flora, p. 39, pl. i, fig. 9.

Delesseria, Lamx.

9. *Delesseria fulva*, Lesqx., Tert. Flora, p. 39, pl. i, fig. 10.

Caulerpites, Schp.

10. *Caulerpites incrassatus*, Lesqx., Tert. Flora, p. 40, pl. i, figs. 11, 12.—*Delesseria incrassata*, Lesqx., Ann. Report, 1872, p. 374; Tert. Flora, p. 40, pl. i, figs. 11, 12.

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11. *Chondrites subsimplex*, Lesqx., Tert. Flora, p. 41, pl. i, fig. 13.
12. *Chondrites bulbosus*, Lesqx., Tert. Flora, p. 42, pl. i, fig. 14.
13. *Chondrites* (species), Heer, Fl. Alask., p. 21, tab. x, fig. 5.

Fucus, Linn.

14. *Fucus lignitum*, Lesqx., Tert. Flora, p. 42, pl. lxi, figs. 24, 24 *a*.

MUSCI.

Hypnum, Linn.

15. *Hypnum Haydenii*, Lesqx., Tert. Flora, p. 44, pl. v, figs. 14, 14 *b*.

FILICES.

Sphenopteris, Brgt.

16. *Sphenopteris Lakesii*, Lesqx., Tert. Flora, p. 49, pl. ii, figs. 1, 1 *a*.—*Sphenopteris eocenica*, Ett., Lesqx., Ann. Report, 1872, p. 376.
17. *Sphenopteris elongata*, Newby., Boston Journ. Nat. Hist., 1863, p. 6.
18. *Sphenopteris membranacea*, Lesqx., Tert. Flora, p. 50, pl. ii, figs. 2, 2 *a*, 3, 3 *a*.
19. *Sphenopteris nigricans*, Lesqx., Tert. Flora, p. 51, pl. ii, figs. 4–5 *a*.

Hymenophyllum, Klf.

20. *Hymenophyllum confusum*, Lesqx., Tert. Flora, p. 51, pl. ii, figs. 6–6 *a*.

Pteris, Linn.

21. *Pteris pseudopennæformis*, Lesqx., Tert. Flora, p. 52, pl. iv, figs. 3, 4.—*Pteris pennæformis*, Heer.—Lesqx., Annual Report, 1873, p. 392.
22. *Pteris subsimplex*, Lesqx., Tert. Flora, p. 52, pl. iv, figs. 5–7.
23. *Pteris erosa*, Lesqx., Tert. Flora, p. 53, pl. iv, fig. 8.
24. *Pteris Sitkensis*, Heer, Flora Alask., p. 21, tab. i, fig. 7 *a*.

Woodwardia, Sm.

25. *Woodwardia latiloba* Lesqx., Tert. Flora, p. 54, pl. iii, figs. 1, 1 *a*.
26. *Woodwardia latiloba* var. *minor*, Lesqx., Tert. Flora, p. 54, pl. iv, figs. 9, 9 *a*.

Diplazium, Sw.

27. *Diplazium Muelleri ?*, Heer, Lesqx., Tert. Flora, p. 55, pl. iv, figs. 10, 10 *a*.

Lastrea, Presl.

28. *Lastrea* (*Goniopteris*) *Goldiana*, Lesqx., Tert. Flora, p. 56, pl. iv, fig. 13.—*Aspidium goldianum*, Lesqx., Annual Report, 1873, p. 393.
29. *Lastrea* (*Goniopteris*) *intermedia*, Lesqx., Tert. Flora, p. 56, pl. iv, fig. 14.—*Aspidium pulchellum ?* or *A. Fischeri*, Heer.—Lesqx., Annual Report, 1870, p. 384.
30. *Lastrea* (*Goniopteris*) *polypodioïdes ?*, Ett., Tert. Flora, p. 57, pl. iv, figs. 11, 12.

Aspidium, Sw.

31. *Aspidium Kennerlyi*, Newby., Boston Journ. Nat. Hist., 1863, p. 8.

Gymnogramma, Desv.

32. *Gymnogramma Gardneri*, Lesqx., Tert. Flora, p. 58, pl. iv, fig. 2.—*Pteris Gardneri*, Lesqx., Annual Report, 1873, p. 393.
33. *Gymnogramma Haydenii*, Lesqx., Tert. Flora, p. 59, pl. v, figs. 1–3.

Osmunda, Linn.

34. *Osmunda affinis*, Lesqx., Tert. Flora, p. 60, pl. iv, fig. 1.—*Pteris affinis*, Lesqx., Annual Report, 1873, p. 392.

Lygodium, Sw.

35. *Lygodium neuropteroides*, Lesqx., Tert. Flora, p. 61, pl. v, figs. 4–7; pl. vi, fig. 1.
36. *Lygodium Marvinei*, Lesqx., Tert. Flora, p. 62, pl. v, fig. 8.
37. *Lygodium Dentoni*, Lesqx., Tert. Flora, p. 63, pl. lxv, figs. 12, 13.
38. *Lygodium compactum*, Lesqx., Tert. Flora, p. 64, pl. v, fig. 9.

Onoclea, L.

39. *Onoclea sensibilis*, Linn.—Newby., Ext. Floras, p. 39, pl. 8, fig. 1; pl. iv, figs. 1–5.
40. *Tæniopteris Gibbsii*, Newby., Boston Journ. Nat. Hist., 1863, p. 7.

RHIZOCARPÆ.

Salvinia, Michx.

41. *Salvinia cyclophylla*, Lesqx., Tert. Flora, p. 64, pl. v, figs. 10, 10 *a*.
42. *Salvinia Alleni*, Lesqx., Tert. Flora, p. 65, pl. v, fig. 11.—*Ophioglossum Alleni*, Lesqx., Annual Report, 1872, p. 371.
43. *Salvinia attenuata*, Lesqx., Tert. Flora, p. 65, pl. lxiv, fig. 14, 14 *a*.

CALAMARIÆ.

EQUISETACEÆ.

Equisetum, Linn.

44. *Equisetum Haydenii*, Lesqx., Tert. Flora, p. 67, pl. vi, figs. 2–4.
45. *Equisetum lævigatum*, Lesqx., Tert. Flora, p. 68, pl. vi. figs. 6, 7.
46. *Equisetum Wyomingense*, Lesqx., Tert. Flora, p. 69, pl. vi, figs. 8–11.
47. *Equisetum robustum*, Newby., Boston Journ. Nat. Hist., 1863, p. 8.
48. *Equisetum limosum?*, Linn., Lesqx., Tert. Flora, p. 69, pl. vi, fig. 5.

LYCOPODIACEÆ.

Lycopodium, Linn.

49. *Lycopodium prominens*, Lesqx., Tert. Flora, p. 45, pl. v, figs. 13, 13 *b*.

Selaginella, Beauv.

50. *Selaginella Berthoudi*, Lesqx., Tert. Flora, p. 46, pl. v, figs. 12, 12 *a*.
51. *Selaginella falcata*, Lesqx., Tert. Flora, p. 46, pl. lxi, figs. 12, 15; pl. lxiv, figs. 13, 13 *a*.
52. *Selaginella laciniata*, Lesqx., Tert. Flora, p. 47, pl. lxiv, figs. 12, 12 *a*.

Psilotum, Swartz.

53. *Psilotum inerme*, Newby., Ext. Floras, p. 38, pl. viii, fig. 3.

PHÆNOGAMÆ.

GYMNOSPERMÆ.

Zamiæ.

Zamiostrobus, Endl.

54. *Zamiostrobus? mirabilis*, Lesqx., Tert. Flora, p. 70, pl. lxiii, figs. 1, 1 *d*.

CONIFERÆ.

CUPRESSINEÆ.

Widdringtonia, Endl.

55. *Widdringtonia? complanata*, Lesqx., Tert. Flora, p. 72, pl. lxii, figs. 13, 14.

Taxodium, Rich.

56. *Taxodium distichum miocenicum*, Heer, Lesqx., Tert. Flora, p. 73, pl. vi, figs. 12–14 *a*.
57. *Taxodium occidentale*, Newby., Boston Journ. Nat. Hist., 1863, p. 11; Ext. Floras, p. 45, pl. xi, figs. 1–3.—*T. dubium*, St., Lesqx., Annual Report, 1872, p. 389; 1873, p. 409.
58. *Taxodium Tinajorum*, Heer, Flora Alask., p. 22, tab. i, figs. 1–5.
59. *Taxodium cuneatum*, Newby., Boston Journ. Nat. Hist., 1863, p. 12.

Taxites, Br.

60. *Taxites microphyllus*, Heer, Flora Alask., p. 24, tab. i, fig. 9.
61. *Taxites Olriki*, Heer, Flora Alask., p. 23, tab. i, fig. 8; tab. ii, fig. 5 *b*.

Thuya, Brgt.

62. *Thuya interrupta*, Newby., Ext. Floras, p. 42, pl. xi, figs. 5, 5 *a*.

Glyptostrobus, Endl.

63. *Glyptostrobus Europæus*, Heer, Lesqx., Tert. Flora, p. 74, pl. vii, figs. 1, 2.—Newby., Ext. Floras, p. 43, pl. xi, figs. 6–8; Boston Journ. Nat. Hist., 1863, p. 12.

ABIETINEÆ.

Sequoia, Torr.

64. *Sequoia affinis*, Lesqx., Tert. Flora, p. 75, pl. vii, figs. 3–5; pl. lxv, figs. 1–4.

65. *Sequoia Langsdorfii*, Brgt., Heer, Foss. Plants of Vancouver, p. 6, pl. i, figs. 1–5.—Newby., Ext. Floras, p. 46, pl. xi, figs. 4, 8, 9.—Lesqx., Tert. Flora, p. 76.
66. *Sequoia angustifolia*, Lesqx., Tert. Flora, p. 77, pl. vii, figs. 6–10.
67. *Sequoia Heerii*, Lesqx., Tert. Flora, p. 77, pl. vii, figs. 11–13.
68. *Sequoia brevifolia*, Heer, Tert. Flora, p. 78, pl. lxi, figs. 25–27.
69. *Sequoia longifolia*, Lesqx., Tert. Flora, p. 79, pl. vii, figs. 14, 14 *a*; pl. lxi, figs. 28, 29.
70. *Sequoia acuminata*, Lesqx., Tert. Flora, p. 80, pl. vii, figs. 15–16*a*.
71. *Sequoia biformis*, Lesqx., Tert. Flora, p. 80, pl. lxii, figs. 15–18 *a*.

Abietites, Goepp.

72. *Abietites dubius*, Lesqx., Tert. Flora, p. 81, pl. vii, figs. 19–24.
73. *Abietites setiger*, Lesqx., Tert. Flora, p. 82, pl. vii, figs. 17, 18.

Pinus, Linn.

74. *Pinus palæostrobus ?*, Ett., Tert. Flora, p. 83, pl. vii, figs. 25–31. *P. polaris*, Heer, Lesqx., Annual Report, 1873, p. 410.
75. *Pinus* (sp.), Heer, Flora Alask., p. 23, tab. i, fig. 11.
76. *Pinites pannonica*, Ung., Heer, Flora Alask., p. 23.

TAXINEÆ.

Salisburia, Sm.

77. *Salisburia binervata*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 412, pl. xv, figs. 3–6.
78. *Salisburia polymorpha*, Lesqx., Tert. Flora, p. 84, pl. lx, figs. 40, 41.

MONOCOTYLEDONES.

GLUMACEÆ.

Arundo, Linn.

79. *Arundo Goepperti ?*, Münst., Tert. Flora, p. 86, pl. viii, figs. 3–5.
80. *Arundo reperta*, Lesqx., Tert. Flora, p. 87, pl. viii, figs. 6–8.
81. *Arundo ? obtusa*, Lesqx., Tert. Flora, p. 87, pl. viii, figs. 9, 9 *c*.

Phragmites, Trin.

82. *Phragmites Œningensis*, Al. Br., Tert. Flora, p. 88, pl. viii, figs. 1–2.
83. *Phragmites Alaskana*, Heer, Lesqx., Tert. Flora, p. 90, pl. viii, f. 10–12.
84. *Phragmites* (sp.), Newby., Ext. Floras, p. 38, pl. vii, figs. 5, 5 *a*.

CYPERACEÆ.

Cyperus, Linn.

85. *Cyperus Chavanensis*, Heer, Tert. Flora, p. 92, pl. ix, figs. 1–2.

Carex, Michx.

86. *Carex Berthoudi*, Lesqx., Tert. Flora, p. 92, pl. ix, figs. 3–4.
87. *Carex servata*, Heer, Flora Alask., p. 24, tab. i, fig. 13.

Poacites, Br.

88. *Poacites tenue-striatus*, Heer, Flora Alask., p. 24, tab. i, fig. 14.

ALISMACEÆ.

89. *Sagittaria pulchella*, Heer, Flor. Alask., p. 25, tab. i, fig. 15.

CORONARIÆ.

SMILACEÆ.

Smilax, Tourn.

90. *Smilax cyclophylla*, Newby., Boston Journ. Nat. Hist., 1863, p. 15.
91. *Smilax grandifolia*, Ung., Lesqx., Tert. Flora, p. 94, pl. ix, fig. 5.

SCITAMINEÆ.

Zingiberaceæ.

Zingiberites, Heer.

92. *Zingiberites dubius*, Lesqx., Tert. Flora, p. 95, pl. xvi, fig. 1.

MUSACEÆ.

Musophyllum, Goepp.

93. *Musophyllum complicatum*, Lesqx., Tert. Flora, p. 96, pl. xv, f. 1-6.

ENSATEÆ.

Hydrocharideæ.

Ottelia, Pers.

94. *Ottelia Americana*, Lesqx., Tert. Flora, p. 98, pl. lxi, fig. 8.

POTAMEÆ.

Najadeæ.

Caulinites, Brgt.

95. *Caulinites sparganioides*, Lesqx., Tert. Flora, p. 99, pl. xiv, figs. 4-11.
96. *Caulinites fecundus*, Lesqx., Tert. Flora, p. 101, pl. xiv, figs. 1-3.

FLUVIALES.

Lemnaceæ.

Lemna, Linn.

97. *Lemna scutata*, Daws., Tert. Flora, p. 102, pl. lxi, figs. 2, 5.

SPADICIFLORÆ.

ARACEÆ.

Pistia, Linn.

98. *Pistia corrugata*, Lesqx., Tert. Flora, p. 103, pl. lxi, f. 1, 3, 4, 6, 7, 9–11.

Aroideæ.

Acorus, Linn.

99. *Acorus brachystachys*, Heer, Tert. Flora, p. 105, pl. xiv, figs. 12–15.
100. *Acorus calamus ?*, Linn., Lesqx., Am. Journ. Sci. and Arts, vol. xxvii. p. 365.

MONOCOTYLEDONES INCERTÆ SEDIS.

Eriocaulon, Gronov.

101. *Eriocaulon ? porosum*, Lesqx., Tert. Flora, p. 106, pl. xvi, figs. 2, 2 *a*.
102. *Phyllites improbatus*, Lesqx., Tert. Flora, p. 107, pl. xiv, fig. 18.—*Rhizocaulon gracile*, Lesqx., Ann. Report, 1873, p. 396.

PRINCIPES.

PALMÆ.

Flabellaria, Schp.

103. *Flabellaria Zinkeni ?*, Heer, Tert. Flora, p. 110, pl. ix, figs. 6, 8.
104. *Flabellaria Eocenica*, Lesqx., Tert. Flora, p. 111, pl. xiii, figs. 1–3.

Sabalites.

105. *Sabalites Grayanus*, Lesqx., Tert. Flora, p. 112, pl. xii, figs. 1, 2.—*Sabal Grayana*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 412, pl. xiv, figs. 4, 5, 6.
106. *Sabalites Californicus*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 1, pl. i, fig. 1.
107. *Sabalites fructifer*, Lesqx., Tert. Flora, p. 114, pl. xi, figs. 3, 3 *a*.—*Flabellaria ? fructifera*, Lesqx., Ann. Report, 1873, p. 396.

Sabal, Adans.

108. *Sabal Campbelli*, Newby., Boston Journ. Nat. Hist., 1863, p. 9; Ext. Floras, p. 41, pl. x.—*Sabalites Campbelli*, Newby., Lesqx., Tert. Flora, p. 113.
109. *Sabal* (sp.), Newby., Boston Journ. Nat. Hist., 1863, p. 10.

Geonomites, Lesqx.

110. *Geonomites Goldianus*, Lesqx., Tert. Flora, p. 115, pl. ix, fig. 9.—*Palmacites Goldianus*, Lesqx., Ann. Report, 1874, p. 311.
111. *Geonomites Schimperi*, Lesqx., Tert. Flora, p. 116, pl. x, fig. 1.
112. *Geonomites tenuirachis*, Lesqx., Tert. Flora, p. 117, pl. xi, fig. 1.—*Flabellaria longirachis ?*, Ung., Lesqx., Ann. Report, 1873, p. 396.
113. *Geonomites Ungeri*, Lesqx., Tert. Flora, p. 118, pl. xi, fig. 2.

Calamopsis, Heer.

114. *Calamopsis Danai*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 411, pl. xiv, figs. 1, 2, 3.

Palmocarpon, Lesqx.

115. *Palmocarpon compositum*, Lesqx., Tert. Flora, p. 119, pl. xi, fig. 4.—*Carpolithes compositus*, Lesqx., Supplement to Annual Report, 1871, p. 16.
116. *Palmocarpon Mexicanum*, Lesqx., Tert. Flora, p. 119, pl. xi, fig. 5.—*Carpolithes Mexicanus*, Lesqx., Supplement to Annual Report, 1871, p. 17.
117. *Palmocarpon commune*, Lesqx., Tert. Flora, p. 119, pl. xiii, figs. 4–7.—*Carpolithes palmarum*, Lesq., Supplement to Annual Report, 1871, p. 13; Annual Report, 1872, pp. 382, 398.
118. *Palmocarpon truncatum*, Lesqx., Tert. Flora, p. 120, pl. xi, figs. 6–9.
119. *Palmocarpon corrugatum*, Lesqx., Tert. Flora, p. 121, pl. xi, f. 10, 11.
120. *Palmocarpon subcylindricum*, Lesqx., Tert. Flora, p. 121, pl. xi, f. 12.

DICOTYLEDONES.

APETALÆ.

AMENTACEÆ.

Myricaceæ.

Myrica, Linn.

121. *Myrica Torreyi*, Lesqx., Tert. Flora, p. 129, pl. xvi, figs. 3–10.
122. *Myrica acuminata*, Ung., Tert. Flora, p. 130, pl. xvii, figs. 1–4.
123. *Myrica Copeana*, Lesqx., Tert. Flora, p. 131, pl. xvii, fig. 5.
124. *Myrica undulata ?*, Heer, Lesqx., Tert. Flora, p. 131, pl. xvii, f. 6–8.
125. *Myrica nigricans*, Lesqx., Tert. Flora, p. 132, pl. xvii, figs. 9–12.
126. *Myrica Bolanderi*, Lesqx., Tert. Flora, p. 133, pl. xvii, fig. 17.
127. *Myrica Ludwigii*, Schp., Tert. Flora, p. 133, pl. lxv, fig. 9.

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128. *Myrica vindobonensis*, Ett., Heer, Flora Alask., p. 27, pl. iii, f. 4, 5.
129. *Myrica banksiæfolia*, Ung., Heer, Flora Alask., p. 28, pl. ii, fig. 11.
130. *Myrica latiloba*, Heer, var. *acutiloba*, Lesqx., Tert. Flora, p. 134, pl. xvii, fig. 13.
131. *Myrica partita*, Lesqx., Tert. Flora, p. 134, pl. xvii, fig. 14.
132. *Myrica Brongniarti*, Ett., Tert. Flora, p. 135, pl. xvii, fig. 15.
133. *Myrica insignis*, Lesqx., Tert. Flora, p. 135, pl. lxv, figs. 7, 8.
134. *Myrica ? Lessigii*, Lesqx., Tert. Flora, p. 136, pl. lxiv, fig. 1.

BETULACEÆ.

Betula, Linn.

135. *Betula prisca*, Ett., Heer, Flora Alask., p. 28, pl. v, figs. 3–6.
136. *Betula grandifolia*, Ett., Heer, Flora Alask., p. 29, pl. v, fig. 8.
137. *Betula Vogdesii*, Lesqx., Tert. Flora, p. 137, pl. xvii, figs. 18, 19.
138. *Betula gracilis*, Ludw., Lesqx., Tert. Flora, p. 138, pl. xvii, fig. 20.
139. *Betula Goepperti*, Lesqx., Tert. Flora, p. 138, pl. xvii, figs. 21–23.

140. *Betula caudata*, Goepp., Lesqx., Annual Report, 1871, p. 293.
141. *Betula Stevensoni*, Lesqx., Tert. Flora, p. 139, pl. xviii, figs. 1–5.
142. *Betula æqualis*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 2, pl. i, figs. 2–4.

Alnus, Tournef.

143. *Alnus Kefersteinii*, Goepp., Lesqx., Tert. Flora, p. 140, pl. xviii, figs. 6–8; pl. lxiv, fig. 11.
144. *Alnus serrata*, Newby., Ext. Floras, p. 55, pl. xvi, figs. 10, 11.

Alnites, Sap.

145. *Alnites inæquilateralis*, Lesqx., Tert. Flora, p. 141, pl. lxii, figs. 1–4.

CUPULIFERÆ.

Carpinus, Linn.

146. *Carpinus grandis*, Ung., Lesqx., Tert. Flora, p. 143, pl. xix, fig. 9; pl. lxiv, figs. 8–10; Geol. of Vermont, p. 716.—Newby., Boston Journ. Nat. Hist., 1863, p. 14.

Corylus, Tourn.

147. *Corylus MacQuarrii*, (Forbes) Heer, Lesqx., Tert. Flora, p. 144, pl. xviii, figs. 9–11.
148. *Corylus grandifolia*, Newby., Ext. Floras, p. 59, pl. xv, fig. 5.
149. *Corylus orbiculata*, Newby., Ext. Floras, p. 58, pl. xv, fig. 4.
150. *Corylus Americana*, Walt., Ext. Floras, p. 59, pl. xiv, figs. 8–10.
151. *Corylus rostrata*, Ait., Newby, Ext. Floras, p. 60, pl. xv, figs. 1–3.

Fagus, Tcurn.

152. *Fagus Feroniæ*, Ung., Heer, Flora Alask., p. 31, pl. vi, fig. 9.—Lesqx., Tert. Flora, p. 146, pl. xix, figs. 1–3.
153. *Fagus macrophylla*, Ung., Heer, Flora Alask., p. 31, pl. viii, fig. 2.
154. *Fagus Antipofi*, Heer, Flora Alask., p. 30, pl. v, fig. 4 *a*; pl. vii, figs. 4–8; pl. viii, fig. 1.—Lesqx. in Whitney's Geol. of the Aurif. Dep., p. 3, pl. ii, fig. 13.
155. *Fagus ferruginea*, Michx., Lesqx., Geol. of Tenn., p. 427, pl. K, fig. 11.
156. *Fagus pseudo-ferruginea*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 3, pl. ii, fig. 14.
157. *Fagus Hitchcockii*, Lesqx., Geol. of Vermont, p. 714, figs. 126, 127.

Quercus, Linn.

§ 1.—*Leaves entire.*

158. *Quercus neriifolia*, Al. Br., Lesqx., Tert. Flora, p. 150, pl. xix, f. 4–5.
159. *Quercus straminea*, Lesqx., Tert. Flora, p. 151, pl. xix, figs. 6–7.
160. *Quercus chlorophylla*, Ung., Lesqx., Tert. Flora, p. 151, pl. xxi, fig. 3.
161. *Quercus cinereoides*, Lesqx., Tert. Flora, p. 152, pl. xxi, fig. 6.
162. *Quercus elænoides*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 4, pl. i, figs. 9–12.
163. *Quercus convexa*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 4, pl. i, fig. 13–17.
164. *Quercus virens*, Michx., Lesqx.. Am. Journ. Sci. and Arts, vol. xxvii, p. 363.

165. *Quercus myrtifolia*, Willd., Lesqx., Geol. of Tenn., p. 427, pl. K, fig. 3.
166. *Quercus coriacea*, Newby., Boston Journ. Nat. Hist., 18 3, p. 15.
167. *Quercus elliptica*, Newby., Boston Journ. Nat. Hist., 1863, p. 17.
168. *Quercus multinervis*, Lesqx., Am. Journ. Sci. and Arts, vol. xxvii, p. 360.
169. *Quercus Benzoin*, Lesqx., Am. Journ., *loc. cit.*, p. 360.
170. *Quercus Evansii*, Lesqx., Am. Journ., *loc. cit.*, p. 360.
171. *Quercus Lyellii*, Heer, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 415, pl. xvii, figs. 1, 2, 3.
172. *Quercus retracta*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 416, pl. xvi, figs. 4, 5.
173. *Quercus chlorophylla*, Ung., Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 416, pl. xvii, figs. 5, 6, 7.

§ 2.—*Leaves serrate, dentate, or crenate.*

174. *Quercus Gaudini*, Lesqx., Am. Journ. Sci. and Arts, vol. xxvii, p. 360.
175. *Quercus, platinervis*, Lesqx., Am. Journ., *loc. cit.*, p. 361.
176. *Quercus Valdensis*, Heer, Lesqx., Tert. Flora, p. 153, pl. xix, fig. 8.
177. *Quercus Godeti?*, Heer, Lesqx., Tert. Flora, p. 153, pl. xx, fig. 1.
178. *Quercus Boweniana*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 6, pl. ii, figs. 5, 6.
179. *Quercus Goepperti*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 7, pl. ii, fig. 11.
180. *Querus Voyana*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 8, pl. ii, fig. 12.
181. *Quercus distincta*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 6, pl. ii, figs. 7, 9.
182. *Quercus Nevadensis*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 5, pl. ii, figs. 3, 4.
183. *Quercus crassinervis*, Ung., Lesqx., Geol. of Tenn., p. 427, pl. K, fig. 1.
184. *Quercus flexuosa*, Newby., Boston Journ. Nat. Hist., 1863, p. 16.
185. *Quercus Saffordi*, Lesqx., Geol. of Tenn., p. 427, pl. K, figs. 2 *a*, *b*, *c*.
186. *Quercus banksiæfolia*, Newby., Boston Journ. Nat. Hist., 1863, p. 17.
187. *Quercus Cleburni*, Lesqx., Tert. Flora, p. 154, pl. xx, fig. 2.
188. *Quercus ? fraxinifolia*, Lesqx., Tert. Flora, p. 154, pl. xx, fig. 3.
189. *Quercus Laharpi*, Gaud., Lesqx., Ann. Report, 1871, p. 297.
190. *Quercus Ellisiana*, Lesqx., Tert. Flora, p. 155, pl. xx, figs. 4, 5, 7, 8.
191. *Quercus Pealei*, Lesqx., Tert. Flora, p. 156, pl. xx, fig. 6.
192. *Quercus Haidingeri*, Ett., Lesqx., Tert. Flora, p. 156, pl. xx, f. 9, 10.
193. *Quercus drymeja*, Ung., Lesqx., Tert. Flora, p. 157, pl. xix, fig. 14.
194. *Quercus Haydenii*, Lesqx., Tert. Flora, p. 157, pl. xix, fig. 10.
195. *Quercus acrodon*, Lesqx., Tert. Flora, p. 158, pl. xix, figs. 11–13.
196. *Quercus Viburnifolia*, Lesqx., Tert. Flora, p. 159, pl. xx, figs. 11–12.—*Quercus attenuata?*, Goepp., Lesqx., Ann. Report, 1873, p. 398.—*Quercus triangularis*, Goepp., Lesqx. (in part), Ann. Report, 1872, p. 377.
197. *Quercus pseudocastanea*, Goepp., Heer, Flora Alask., p. 32, pl. vi, figs. 3–5.
198. *Quercus Furuhjelmi*, Heer, Flora Alask., p. 32, pl. v, fig. 10; pl. vi, figs. 1, 2.
199. *Quercus pandurata*, Heer, Flora Alask., p. 33, pl. vi, fig. 6.
200. *Quercus Chamissoni*, Heer, Flora Alask., p. 33, pl. vi, figs. 7, 8.
201. *Quercus platania*, Heer, Lesqx., Tert. Flora, p. 160, pl. xxi, fig. 1.
202. *Quercus Moorii*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 415, pl. xvi, figs. 1, 2, 3.

§ 3.—*Leaves lobate, border entire.*

203. *Quercus negundoides*, Lesqx., Tert. Flora, p. 161, pl. xxi, fig. 2.
204. *Quercus pseudo-lyrata*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 8, pl. ii, figs. 1, 2.
205. *Quercus angustiloba*, Al. Br., Lesqx., Tert. Flora, p. 161, pl. xxi, figs. 4, 5.

Dryophyllum, Debey.

206. *Dryophyllum* (*Quercus*) *crenatum*, Lesqx., Tert. Flora, p. 162, pl. lxii, figs. 10 and 11.—*Dryophyllum crenatum*, Lesqx., Ann. Report, 1874, p. 301.
207. *Dryophyllum* (*Quercus*) *subfalcatum*, Lesqx., Tert. Flora, p. 163, pl. lxiii, fig. 10.

Castanea, Tourn.

208. *Castanea intermedia*, Lesqx., Tert. Flora, p. 164, pl. xxi, fig. 7.
209. *Castanea Ungeri*, Heer, Flora Alask., p. 32, pl. vii, figs. 1–3.
210. *Castanea nana*, Muhl., Lesqx., Am. Journ. Sci. and Arts, vol. xxvii, p. 365.

Castaneopsis, Sap.

211. *Castaneopsis chrysophylloides*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 9, pl. ii, fig. 10.

SALICINEÆ.

Salix, Linn.

212. *Salix integra*, Goepp., Tert. Flora, p. 167, pl. xxii, figs. 1, 2.
213. *Salix media*, Heer, Lesqx., Tert. Flora, p. 168, pl. xxii, fig. 3.
214. *Salix angusta*, Al. Br., Lesqx., Tert. Flora, p. 168, pl. xxii, figs. 4–5.
215. *Salix elongata*, O. Web., Lesqx., Tert. Flora, p. 169, pl. xxii, figs. 6, 7.
216. *Salix? densinervis*, Lesqx., Geol. of Tenn., p. 427, pl. K, fig. 9.
217. *Salix Worthenii*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 414, pl. xv, fig. 7.
218. *Salix californica*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 10, pl. i, figs. 18–21.
219. *Salix tabellaris*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 414, pl. xvii, fig. 4.
220. *Salix macrophylla*, Heer, Flora Alask., p. 27, pl. ii, fig. 9.
221. *Salix Lavateri*, Heer, Flora Alask., p. 27, pl. ii, fig. 10.
222. *Salix elliptica*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 10, pl. i, fig. 22.
223. *Salix Islandica*, Lesqx., Am. Journ. Sci. and Arts, vol. xxvii, p. 360.
224. *Salix varians*, Goepp., Heer, Flora Alask., p. 27, pl. ii, fig. 8; pl. iii, figs. 1, 2, 3.

Populus, Linn.

225. *Populus latior*, Al. Br., Heer, Flora Alask., p. 25, pl. ii, fig. 4; var. *cordifolia*, Lesqx., Tert. Flora, p. 172, pl. xxii, fig. 8.
226. *Populus subrotundata*, Lesqx., Tert. Flora, p. 173, pl. xxiv, figs. 6–8.
227. *Populus glandulifera*, Heer, Flora Alask., p. 26, pl. ii, figs. 1, 2.
228. *Populus balsamoides*, Goepp., Flora Alask., p. 26, pl. ii, fig. 3.
229. *Populus leucophylla*, Ung., Flora Alask, p. 26, pl. ii, fig. 6.
230. *Populus melanaria*, Heer, Lesqx., Tert. Flora, p. 173, pl. lxiv, fig. 5.

231. *Populus melanarioides*, Lesqx., Tert. Flora, p. 174, pl. lxii, fig. 5.
232. *Populus Ungeri*, Lesqx., Tert. Flora, p. 175, pl. xxiv, fig. 5.
233. *Populus heliadum*, Ung., Lesqx., Ann. Report, 1873, p. 397.
234. *Populus lævigata*, Lesqx., Tert. Flora, p. 175, pl. xxii, fig. 9.
235. *Populus Zaddachi*, Heer, Flora Alask., p. 26, pl. ii, fig. 5 *a*.—Lesqx. Tert. Flora, p. 176, pl. xxii, fig. 13; Whitney's Geol. of the Aurif. Dep., p. 11, pl. 8, figs. 1–8.
236. *Populus Richardsoni*, Heer, Lesqx., Tert. Flora, p. 177, pl. xxii, figs. 10–12.
237. *Populus rhomboidea*, Lesqx., Am. Journ. Sci. and Arts, vol. xxvii, p. 360.—Newby., Boston Journ. Nat. Hist., 1863, p. 18.
238. *Populus monodon*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 413, pl. xv, figs. 1, 2; Tert. Flora, p. 180, pl. xxiv, figs. 1, 2.
239. *Populus mutabilis*, var. *repando-crenata*, Heer, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 413, pl. xviii, figs. 4, 5, 6.
240. *Populus mutabilis*, var. *f. ovalis*, Heer, Lesqx., Tert. Flora, p. 177, pl. xxiv, figs. 3, 4.
241. *Populus arctica*, Heer, Lesqx., Tert. Flora, p. 178, pl. xxiii, figs. 1–6.
242. *Populus decipiens*, Lesqx., Tert. Flora, p. 179, pl. xxiii, figs. 7–11.
243. *Populus Nebrascencis*, Newby., Ext. Floras, p. 62, pl. xii, figs. 4, 5.
244. *Populus cuneata*, Newby., Ext. Floras, p. 64, pl. xiv, figs. 1–4.
245. *Populus genetrix*, Newby., Ext. Floras, p. 64, pl. xii, fig. 1.
246. *Populus acerifolia*, Newby., Ext. Floras, p. 65, pl. xiii, figs. 5–8.
247. *Populus smilacifolia*, Newby., Ext. Floras, p. 66, pl. xiv, figs. 5–7.
248. *Populus cordata*, Newby., Ext. Floras, p. 60, pl. xiv, fig. 6.
249. *Populus nervosa*, Newby., Ext. Floras, p. 61, pl. xii, figs. 2, 3.
250. *Populus nervosa*, Newby., var. *elongata*, Ext. Floras, p. 62, pl. xiii, figs. 1–4.
251. *Populus flabellum*, Newby., Boston Journ. Nat. Hist., 1863, p. 18.

PLATANEÆ.

Platanus, Tour.

252. *Platanus Guillelmæ*, Goepp., Lesqx., Tert. Flora, p. 183, pl. xxv, figs. 1, 2, 3.
253. *Platanus aceroides*, Goepp., Lesqx., Tert. Flora, p. 184, pl. xxv, figs. 4, 5, 6.
254. *Platanus appendiculata*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 12, pl. iii, figs. 1–6; pl. vi, fig. 7 *b*.
255 *Platanus dissecta*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 13, pl. vii, fig. 12; pl. x, figs. 4, 5.
256. *Platanus Haydenii*, Newby., Ext. Floras, p. 70, pl. xx, fig. 1; pl. xxi.
257. *Platanus Raynoldsii*, Newby., Ext. Floras, p. 69, pl. xviii.—Lesqx., Tert. Flora, p. 185, pl. xxvi, figs. 4–5; pl. xxvii, figs. 1–3.
258. *Platanus rhomboidea*, Lesqx., Tert. Flora, p. 186, pl. xxvi, figs. 6, 7.
259. *Platanus nobilis*, Newby., Ext. Floras, p. 67, pl. xvii.

Styracifluæ.

260. *Liquidambar Europæum*, Al. Br., Heer, Flora Alask., p. 25, pl. ii, fig. 7.
261. *Liquidambar Californicum*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 14, pl. 7, figs. 3, 6; pl. 6, fig. 7 *c*.

URTICINÆ.

ULMACEÆ.

Ulmus, Linn.

262. *Ulmus tenuinervis*, Lesqx., Tert. Flora, p. 188, pl. xxvi, figs. 1–3.
263. *Ulmus plurinervia*, Ung., Heer, Flora Alask., p. 34, pl. v, fig. 1.
264. *Ulmus affinis*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 16, pl. iv, figs. 4, 5.
265. *Ulmus pseudo fulva*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 17, pl. iv, fig. 3.
266. *Ulmus Californica*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 15, pl. iv, figs. 1–2; pl. vi, fig. 7 *a*.

Planera, Gmel.

267. *Planera longifolia*, Lesqx., Tert. Flora, p. 189, pl. xxvii, figs. 4–6.
268. *Planera Ungeri*, Ett., Lesqx., Tert. Flora, p. 190, pl. xxvii, fig. 7.
269. *Planera microphylla*, Newby., Ext. Floras, p. 55, pl. xvi, figs. 3, 4.
270. *Planera dubia*, Lesqx., Am. Journ. Sci. and Arts, vol. xxvii, p. 361.
271. *Planera Gmelini*, Michx., Lesqx., Am. Journ. Sci. and Arts, vol. xxvii, p. 365.

CELTIDEÆ.

Celtis, Tournf.

272. *Celtis brevifolia*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 416, pl. xx, figs. 4, 5.

MOREÆ.

Ficus, Tournf.

§ 1.—*Penninerved leaves.*

273. *Ficus lanceolata*, Heer, Lesqx., Tert. Flora, p. 192, pl. xxviii, figs. 1–5.
274. *Ficus Iynx*, Ung., Lesqx., Tert. Flora, p. 193, pl. xxviii, fig. 6.
275. *Ficus multinervis*, Heer, Lesqx., Tert. Flora, p. 194, pl. xxviii, figs. 7, 8.
276. *Ficus oblanceolata*, Lesqx., Tert. Flora, p. 194, pl. xxviii, figs. 9–12.
277. *Ficus arenacea*, Lesqx., Tert. Flora, p. 195, pl. xxix, figs. 1–5.
278. *Ficus Ungeri*, Lesqx., Tert. Flora, p. 195, pl. xxx, fig. 3.
279. *Ficus irregularis*, Lesqx., Tert. Flora, p. 196, pl. xxxiv, figs. 4–7; pl. lxiii, fig. 9.
280. *Ficus uncata*, Lesqx., Tert. Flora, p. 197, pl. xxxv, figs. 1, 1 *a*, 2.—*Ficus ulmifolia*, Lesqx., Ann. Report of 1871, Supplement, p. 14.
281. *Ficus Haydenii*, Lesqx., Tert. Flora, p. 197, pl. xxx, fig. 1.
282. *Ficus ovalis*, Lesqx., Tert. Flora, p. 198, pl. xxx, fig. 2.
283. *Ficus dalmatica*, Ett., Lesqx., Tert. Flora, p. 199, pl. lxiii, figs. 3–5.
284. *Ficus spectabilis*, Lesqx., Tert. Flora, p. 199, pl. xxxiii, figs. 4, 5, 6.
285. *Ficus ? Smithsoniana*, Lesqx., Tert. Flora, p. 200, pl. xxxii, fig. 5.
286. *Ficus cuneata*, Newby., Boston Journ. of Nat. Hist., 1863, p. 19.
287. *Ficus ?* (species), Lesqx., Am. Journ. Sci. and Arts, vol. xxvii, p. 361.

§ 2.—*Palmately-nerved leaves.*

288. *Ficus occidentalis*, Lesqx., Tert. Flora, p. 200, pl. xxxii, fig. 4.—*Dombeyopsis occidentalis*, Lesqx., Ann. Report, 1872, p. 380.
289. *Ficus planicostata*, Lesqx., Tert. Flora, p. 201, pl. xxxi, figs. 1–8, 10, 11, 12.
290. *Ficus planicostata* var. *latifolia*, Lesqx., Tert. Flora, p. 202, pl. xxxi, fig. 9.
291. *Ficus planicostata* var. *Goldiana*, Lesqx., Tert. Flora, p. 202, pl. xxxiii, figs. 1, 1 *a*, 2, 3.—*Ficus Clintoni*, Lesqx., Ann. Report, 1872, p. 393.
292. *Ficus Schimperi*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 417, pl. xviii, figs. 1, 2, 3.
293. *Ficus sordida*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 17, pl. iv, figs. 6, 7.
294 *Ficus tiliæfolia*, Al. Br., Lesqx., Tert. Flora, p. 203, pl. xxxii, figs. 1, 2, 2 *a*, 3; pl. lxiii, fig. 8; Whitney's Geol. of the Aurif. Dep., p. 18, pl. 4, figs. 8, 9.
295. *Ficus microphylla*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 18, pl. iv, figs. 10, 11.
296. *Ficus cinnamomoides*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 417, pl. xvii, fig. 8.
297. *Ficus pseudo-populus*, Lesqx., Tert. Flora, p. 204, pl. xxxiv, figs. 1 *a*, 2.
298. *Ficus Wyomingiana*, Lesqx., Tert. Flora, p. 205, pl. xxxiv, fig. 3.
299. *Ficus subtruncata*, Lesqx., Tert. Flora, p. 205, pl. xxx, figs. 7–9.
300. *Ficus auriculata*, Lesqx., Tert. Flora, p. 206, pl. xxx, figs. 4–6.
301. *Ficus asarifolia*, Ett., Lesqx., Tert. Flora, p. 207, pl. lxi, figs. 18–21.

OLERACEÆ.

POLYGONEÆ.

Coccoloba, Jacq.

302. *Coccoloba lævigata*, Lesqx., Tert. Flora, p. 208, pl. xxxv, fig. 7.

NYCTIAGINEÆ.

Pisonia, Plum.

303. *Pisonia racemosa*, Lesqx., Tert. Flora, p. 209, pl. xxxv, fig. 4.

SERPENTARIÆ.

Aristolochia, Tourn.

304. *Aristolochia cordifolia*, Newby., Ext. Floras, p. 74, pl. xxv, fig. 7.
305. *Aristolochia Œningensis*, Heer, Lesqx., Geol. of Vermont, p. 715, fig. 134.
306. *Aristolochia curvata*, Lesqx., Geol. of Vermont, p. 715, figs. 135, 136.
307. *Aristolochia obscura*, Lesqx., Geol. of Vermont, p. 715, figs. 137, 138, 141.

PROTEINEÆ.

PROTEEÆ.

Lomatia, R. Br.

308. *Lomatia? microphylla*, Lesqx., Tert. Flora, p. 211, pl. lxv, f. 14, 15.

LAURINEÆ.

Laurus, Linn.

309. *Laurus socialis*, Lesqx., Tert. Flora, p. 213, pl. xxxvi, f. 1, 2, 3, 4, 7.
310. *Laurus primigenia*, Ung., Lesqx., Tert. Flora, p. 214, pl. xxxvi, figs. 5, 6, 8.
311. *Laurus ocoteoides*, Lesqx., Tert. Flora, p. 215, pl. xxxvi, fig. 10.
312. *Laurus præstans*, Lesqx., Tert. Flora, p. 215, pl. lxiii, fig. 7.
313. *Laurus Utahensis*, Lesqx., Tert. Flora, p. 216, pl. xxxvi, fig. 11.
314. *Laurus Brossiana*, Lesqx., Tert. Flora, p. 216, pl. xxxvi, fig. 9.

Persea, Gaert.

315. *Persea pseudo-Carolinensis*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 19, pl. vii, figs. 1, 2.

Tetranthera, Jack.

316. *Tetranthera sessiliflora*, Lesqx., Tert. Flora, p. 217, pl. xxxiv, figs. 1 *c*, 1 *d*; pl. xxxv, figs. 8, 9.

Cinnamomum, Burm.

317. *Cinnamomum lanceolatum*, Ung., Lesqx., Tert. Flora, p. 219, pl. xxxvi, fig. 12.
318. *Cinnamomum Scheuchzeri*, Heer, Lesqx., Tert. Flora, p. 220, pl. xxxvii, fig. 8.
319. *Cinnamomum polymorphum*, Al. Br., Lesqx., Tert. Flora, p. 221, pl. xxxvii, figs. 6, 10.
320. *Cinnamomum affine*, Lesqx., Tert. Flora, p. 219, pl. xxxvii, figs. 1–5, 7.
321. *Cinnamomum Mississippiense*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 418, pl. xix, fig. 2.
322. *Cinnamomum Heerii*, Lesqx., Am. Journ. Sci. and Arts, vol. xxvii, p. 361.—Newby., Boston Journ. Nat. Hist., 1863, p. 13.
323. *Cinnamomum crassipes*, Lesqx., Am. Journ. Sci. and Arts, vol. xxvii, p. 361.
324. *Cinnamomum Novæ-Angliæ*, Lesqx., Geol. of Vermont, p. 716, fig. 148.

Daphnogene, Ung.

325. *Daphnogene anglica ?*, Heer, Lesqx., Tert. Flora, p. 222, pl. xxxvii, fig. 9.

GAMOPETALÆ.

LONICEREÆ.

Viburnum, Linn.

326. *Viburnum marginatum*, Lesqx., Tert. Flora, p. 223, pl. xxxvii, fig. 11; pl. xxxviii, figs. 1–5.
327. *Viburnum platanoides*, Lesqx., Tert. Flora, p. 224, pl. xxxviii, f. 8, 9.
328. *Viburnum rotundifolium*, Lesqx., Tert. Flora, p. 225, pl. xxxvii, fig. 12; pl. xxxviii, fig. 10; pl. lxi, fig. 22.
329. *Viburnum dichotomum*, Lesqx., Tert. Flora, p. 225, pl. xxxviii, fig. 6.

330. *Viburnum Whymperi ?*, Heer, Lesqx., Tert. Flora, p. 225, pl. xxxviii, fig. 7; pl. lxi, fig. 23.
331. *Viburnum Lakesii*, Lesqx., Tert. Flora, p. 226, pl. xxxvii, fig. 13.
332. *Viburnum anceps*, Lesqx., Tert. Flora, p. 227, pl. xxxviii, fig. 11.
333. *Viburnum asperum*, Newby., Ext. Floras, p. 54, pl. xvi, fig. 8.
334. *Viburnum lanceolatum*, Newby., Ext. Floras, p. 54, pl. xvi, fig. 9.
335. *Viburnum Nordenskioldi*, Heer, Flora Alask., p. 36, pl. iii, fig. 13.
336. *Viburnum Goldianum*, Lesqx., Tert. Flora, p. 227, pl. lx, figs. 2–2 *c*.
337. *Viburnum solitarium*, Lesqx., Tert. Flora, p. 227, pl. lx, fig. 3.

THYMELACEÆ.

Elæagnus, Linn.

338. *Elæagnus inæqualis*, Lesqx., Geol. of Tenn., p. 428, pl. K, fig. 7.

ASCLEPIADINEÆ.

OLEACEÆ.

Fraxinus, Tourn.

339. *Fraxinus denticulata*, Heer, Lesqx., Tert. Flora, p. 228, pl. xl, f. 1, 2.
340. *Fraxinus prædicta*, Heer, Tert. Flora, p. 229, pl. xl, fig. 3.
341. *Fraxinus Eocenica*, Lesqx., Tert. Flora, p. 229.
341 *a*. *F. Brownellii*, Lesqx., Tert. Flora, p. 230.

DIOSPYRINEÆ.

EBENACEÆ.

Diospyros, Linn.

342. *Diospyros lancifolia*, Lesqx., Am. Journ. Sci. and Arts, vol. xxvii, p. 361.—Heer, Foss. Plants of Vancouver, p. 8, pl. 1, figs. 10–12; pl. 2, figs. 1, 2, 3.
343. *Diospyros stenosepala*, Heer, Flora Alask., p. 35, pl. viii, figs. 7, 8.
344. *Diospyros ficoidea*, Lesqx., Tert. Flora, p. 231, pl. xl, figs. 5, 6.
345. *Diospyros brachysepala*, Al. Br., Lesqx., Tert. Flora, p. 232, pl. xl, figs. 7–10; pl. lxiii, fig. 6.
346. *Diospyros Copeana*, Lesqx., Tert. Flora, p. 232, pl. xl, fig. 11.
347. *Diospyros Wodani*, Ung., Tert. Flora, p. 233, pl. lix, fig. 13.—*Calycites hexaphylla*, Lesqx., Ann. Report, 1872, p. 402.

Sapotacites, Ett.

348. *Sapotacites Americanus*, Lesqx., Geol. of Tenn., p. 428, pl. K, fig. 8.

ERICINEÆ.

ERICACEÆ.

Andromeda, Linn.

349. *Andromeda Grayana*, Heer, Foss. Plants of Vancouver, p. 7, pl. 1, figs. 7–9.—Lesqx., Tert. Flora, p. 234, pl. xl, fig. 4.
350. *Andromeda reticulata ?*, Lesqx., Ann. Report, 1871, p. 298.
351. *Andromeda dubia*, Lesqx., Geol. of Tenn., p. 428, pl. K, fig. 5.
352. *Andromeda vaccinifoliæ affinis*, Lesqx., Geol. of Tenn., p. 428, pl. K, fig. 4, *a*, *b*.

Vaccinium, Rupp.

353. *Vaccinium Friesii*, Heer, Flora Alask., p. 35, pl. viii, fig. 4.
354. *Vaccinium reticulatum?*, Al. Br., Lesqx., Tert. Flora, p. 235, pl. lix, fig. 6.

POLYPETALÆ.

UMBELLIFLORÆ.

Araliaceæ.

Aralia, Tourn.

355. *Aralia gracilis*, Lesqx., Tert. Flora, p. 236, pl. xxxix, fig. 1.—*Liquidambar gracile*, Lesqx., Annual Report, 1871, p. 287.
356. *Aralia angustiloba*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 22, pl. 5, figs. 4, 5.
357. *Aralia Whitneyi*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 20, pl. v, fig. 1.
358. *Aralia Zaddachi?*, Heer, Lesqx. in Whitney's Geol. of the Aurif. Dep., p. 21, pl. v, figs. 2, 3.
359. *Aralia triloba*, Newby., Ext. Floras, p. 58, pl. xxv, figs. 4, 5.
360. *Aralia notata*, Lesqx., Tert. Flora, p. 237, pl. xxxix, figs. 2–4.—*Platanus dubia*, Lesqx., Annual Report, 1873, p. 406.

Hedera, Linn.

361. *Hedera auriculata*, Heer, Flora Alask., p. 36, pl. ix, fig. 6.

AMPELIDEÆ.

Cissus, D. C.

362. *Cissus lævigata*, Lesqx., Tert. Flora, p. 238, pl. xl, figs. 12, 13.
363. *Cissus Parrotiæfolia*, Lesqx., Tert. Flora, p. 239, pl. xl, figs. 15–17; pl. xlii, fig. 1.
364. *Cissus lobato-crenata*, Lesqx., Tert. Flora, p. 240, pl. xli, figs. 1–3.
365. *Cissus tricuspidata*, Heer, Lesqx., Tert. Flora, p. 240, pl. xli, f. 4–7.

Vitis, Linn.

366. *Vitis crenata*, Heer, Flora Alask., p. 36, pl. viii, fig. 6.
367. *Vitis Olriki*, Heer, Lesqx., Tert. Flora, p. 241, pl. xli, fig. 8.
368. *Vitis sparsa*, Lesqx., Tert. Flora, p. 241, pl. lx, fig. 24.

Ampelopsis, Michx.

369. *Ampelopsis tertiaria*, Lesqx., Tert. Flora, p. 242, pl. xliii, fig. 1.

CORNEÆ.

Cornus, Tourn.

370. *Cornus suborbifera*, Lesqx., Tert. Flora, p. 243, pl. xlii, fig. 2.—*Cornus obifera*, (Heer) Lesqx., Annual Report, 1873, p. 402.
371. *Cornus ovalis*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 23, pl. 6, figs. 1, 2.

372. *Cornus Kelloggii*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 23, pl. 6, fig. 3.
373. *Cornus impressa*, Lesqx., Tert. Flora, p. 243, pl. xlii, fig. 3.
374. *Cornus Studeri?*, Heer, Lesqx., Tert. Flora, p. 244, pl. xlii, figs. 4, 5.
375. *Cornus rhamnifolia*, O. Web., Lesqx., Tert. Flora, p. 244, pl. xlii, fig. 6.
376. *Cornus acuminata*, Newby., Ext. Floras, p. 71, pl. xx, figs. 2, 3, 4.

NYSSEÆ.

Nyssa, Linn.

377. *Nyssa lanceolata*, Lesqx., Tert. Flora, p. 245, pl. xxxv, figs. 5, 6.
378. *Nyssa complanata*, Lesqx., Geol. of Vermont, p. 717, fig. 153.
379. *Nyssa microcarpa*, Lesqx., Geol. of Vermont, p. 717, fig. 154.
380. *Nyssa lævigata*, Lesqx., Geol. of Vermont, p. 717, fig. 151.

CORNICULACEÆ.

SAXIFRAGEÆ.

Callicoma, Andrews.

381. *Callicoma microphylla*, Ett., Lesqx., Tert. Flora, p. 246, pl. xliii, figs. 2–4.—*Rhus? Drymeja*, Lesqx., Ann. Report, 1873, p. 416.

POLYCARPICÆ.

MAGNOLIACEÆ.

Magnolia, Linn.

382. *Magnolia Lesleyana*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 421; pl. xxi, figs. 1, 2; Tert. Flora, p. 248, pl. xliv, figs. 1–3.
383. *Magnolia Hilgardiana*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 421, pl. xx, fig. 1; Tert. Flora, p. 249, pl. xliv, fig. 4.
384. *Magnolia Californica*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 25, pl. 6, figs. 5, 7.
385. *Magnolia lanceolata*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 24, pl. 6, fig. 4.
386. *Magnolia laurifolia*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 421, pl. xx, figs. 2, 3.
387. *Magnolia cordifolia*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 422, pl. xvii, figs. 1, 2.
388. *Magnolin ovalis*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 422, pl. xxi, figs. 3, 4.
389. *Magnolia tenuinervis*, Lesqx., Tert. Flora, p. 249, pl. xliv, figs. 5, 6; pl. xlv, figs. 1–5.—*Magnolia Inglefieldi*, (Heer) Lesqx., Ann. Report of 1872, p. 396.
390. *Magnolia attenuata*, Web., Tert. Flora, p. 250, pl. xlv, fig. 6.—*Terminalia Radobojensis*, (Ung.) Lesqx., Supplement to Ann. Report, 1871, p. 15.
391. *Magnolia* fruit, Whitney's Geol. of the Aurif. Dep., p. 25, pl. 6, f. 6.

ANONACEÆ.

Asimina, Adans.

392. *Asimina Eocenica*, Lesqx., Tert. Flora, p. 251, pl. xliii, figs. 5, 8.
393. *Asimina Leiocarpa*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 422, pl. xv, fig. 8.

NYMPHEINEÆ.

NELUMBONÆ.

Nelumbium, Linn.

394. *Nelumbium Lakesii*, Lesqx., Tert. Flora, p. 252, pl. xlvi, figs. 1, 2.
395. *Nelumbium tenuifolium*, Lesqx., Tert. Flora, p. 253, pl. xlvi, fig. 3.

Illicium, Linn.

396. *Illicium lignitum*, Lesqx., Geol. of Vermont, p. 716, fig. 149.

MALVOIDEÆ.

BUTTNERIACEÆ.

Dombeycpsis, Ung. (emend.).

397. *Dombeyopsis platanoides*, Lesqx., Tert. Flora, p. 254, pl. xlvii, f. 1, 2.
398. *Dombeyopsis trivialis*, Lesqx., Tert. Flora, p. 255, pl. xlvii, fig. 3.
399. *Dombeyopsis obtusa*, Lesqx., Tert. Flora, p. 255, pl. xlvii, figs. 4, 5.
400. *Dombeyopsis grandifolia*, Ung., Lesqx., Tert. Flora, p. 255, pl. xlvii, fig. 6.

TILIACEÆ.

Tilia, Linn.

401. *Tilia alaskana*, Heer, Flora Alask., p. 36, pl. x, figs. 2, 3.
402. *Tilia antiqua*, Newby., Ext. Floras, p. 52, pl. xvi, figs. 1, 2.

Grewiopsis, Sap.

403. *Grewiopsis Saportana*, Lesqx., Tert. Flora, p. 257, pl. l, figs. 10–12.—*Aleurites Eocenica*, Lesqx., Ann. Report, 1872, p. 397.
404. *Grewiopsis tenuifolia*, Lesqx., Tert. Flora, p. 258, pl. xl, fig. 14.
405. *Grewiopsis Cleburni*, Lesqx., Tert. Flora, p. 259, pl. lxii, fig. 12.

Apeibopsis, Heer.

406. *Apeibopsis ? discolor*, Lesqx., Tert. Flora, p. 259, pl. xlvi, figs. 4–7.
407. *Apeibopsis Heerii*, Lesqx., Geol. of Vermont, p. 715, figs. 131, 132, 133.
408. *Apeibopsis Gaudini*, Lesqx., Geol. of Vermont, p. 715, figs. 139, 140.

ACERINEÆ.

ACERACEÆ.

Acer, Linn.

409. *Acer trilobatum* var. *productum*, Al. Br., Lesqx., Tert. Flora, p. 261, pl. xlviii, figs. 2, 3 *a*.
410. *Acer trilobatum?*, Al. Br., Lesqx., Am. Journ. Sci. and Arts, vol. xxvii, p. 361.
411. *Acer æquidentatum*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 26, pl. 7, figs. 4, 5; Tert. Flora, p. 262, pl. xlviii, figs. 1–3.
412. *Acer Bolanderi*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 27, pl. 7, figs. 7, 11.
413. *Acer macropterum*, Heer, Flora Alask., p. 37, pl. ix, figs. 7–9.

Negundo, Moench.

414. *Negundo triloba*, Newby., Ext. Floras, p. 57, pl. xxiii, fig. 5.

HYPPOCASTANEÆ.

Æsculus, Linn.

415. *Æsculus antiquus*, Daws., B. N. Am. Boundary Commission Report, p. 330.

SAPINDACEÆ.

Sapindus, Linn.

416. *Sapindus stellariæfolius*, Lesqx., Tert. Flora, p. 264, pl. xlix, fig. 1.—*Sapindus angustifolius*, Lesqx., Annual Report, 1873, p. 415.
417. *Sapindus angustifolius*, Lesqx., Tert. Flora, p. 265, pl. xlix, figs. 2–7.
418. *Sapindus coriaceus*, Lesqx., Tert. Flora, p. 265, pl. xlix, figs. 12–14.
419. *Sapindus Dentoni*, Lesqx., Tert. Flora, p. 265, pl. lxiv, figs. 2–4.
420. *Sapindus caudatus*, Lesqx., Tert. Flora, p. 264, pl. xlviii, fig. 6.
421. *Sapindus affinis*, Newby., Ext. Floras, p. 51, pl. xxiv, fig. 1.
422. *Sapindus undulatus*, Al. Br., Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 420, pl. xxii, fig. 6.
423. *Sapindus obtusifolius*, Lesqx., Tert. Flora, p. 266, pl. xlix, figs. 8–11.
424. *Sapindus membranaceus*, Newby., Ext. Floras, p. 52, pl. xxiv, f. 2, 3.
425. *Sapindus Americanus*, Lesqx., Geol. of Vermont, p. 715, figs. 142, 143, 144, 145.

BIGNONIACEÆ.

Catalpa, Scop.

426. *Catalpa crassifolia*, Newby., Ext. Floras, p. 56, pl. xxii, fig. 1.

FRANGULACEÆ.

STAPHYLEACEÆ.

Staphylea, Linn.

427. *Staphylea acuminata*, Lesqx., Tert. Flora, p. 267, pl. xlviii, figs. 4, 5.

CELASTREÆ.

Celastrus, Linn.

428. *Celastrus borealis*, Heer, Flora Alask., p. 37, pl. x, fig. 4.

Celastrinites, Sap.

429. *Celastrinites artocarpidioides*, Lesqx., Tert. Flora, p. 268, pl. xxxv, fig. 3.—*Artocarpidium olmediæfolium*, Ung., Lesqx., Ann. Rep. of 1873, p. 400.
430. *Celastrinites lævigatus*, Lesqx., Tert. Flora, p. 269, pl. xvii, figs. 16, 16 *a*.—*Myrica ambigua*, Lesqx., Ann. Rep., 1871, p. 297.

ILICEÆ.

Prinos, Linn.

431. *Prinos integrifolia*, Ell., Lesqx., Am. Journ. Sci. and Arts, vol. xxvii, p. 365.

Ilex, Linn.

432. *Ilex insignis*, Heer, Flora Alask., p. 37, pl. x, fig. 1.
433. *Ilex prunifolia*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 27, pl. 9, fig. 7.
434. *Ilex Wyomingiana*, Lesqx., Tert. Flora, p. 270, pl. l, fig. 1.
435. *Ilex affinis*, Lesqx., Tert. Flora, p. 270, pl. l, figs. 2–3.
436. *Ilex subdenticulata*, Lesqx., Tert. Flora, p. 271, pl. l, figs. 5, 6, 6 *a*, 6 *b*.
437. *Ilex dissimilis*, Lesqx., Tert. Flora, p. 271, pl. l, figs. 7–9.—*Quercus Ilicoides*, (Heer) Lesqx., Ann. Rep., 1871, p. 291.

RHAMNEÆ.

Paliurus, Tourn.

438. *Paliurus colombi*, Heer, Lesqx., Tert. Flora, p. 273, pl. l, figs. 13–17.
439. *Paliurus Florissanti*, Lesqx., Tert. Flora, p. 274, pl. l, fig. 18.
440. *Paliurus zizyphoides*, Lesqx., Tert. Flora, p. 274, pl. li, figs. 1–6.

Zizyphus, Mill.

441. *Zizyphus distortus*, Lesqx., Tert. Flora, p. 275, pl. li, figs. 7–9.
442. *Zizyphus Meekii*, Lesqx., Tert. Flora, p. 275, pl. li, figs. 10–14.
443. *Zizyphus hyperboreus*, Heer, Lesqx., Tert. Flora, p. 276, pl. li, fig. 15.
444. *Zizyphus cinnamomoides*, Lesqx., Tert. Flora, p. 277, pl. lii, figs. 7, 8.
445. *Zizyphus fibrillosus*, Lesqx., Tert. Flora, p. 276, pl. lii, figs. 1–6.—*Ceanothus fibrillosus*, Lesqx., Annual Report, 1872, p. 381.
446. *Zizyphus piperoides*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 28, pl. 8, figs. 10, 11.
447. *Zizyphus microphyllus*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 28, pl. 8, fig. 9.

Ceanothus, Linn.

448. *Ceanothus Americanus ?*, Linn., Lesqx., Am. Journ. Sci. and Arts, vol. xxvii, p. 365.
449. *Ceanothus Meigsii*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 419, pl. xx, figs. 5, 6, 7.

Berchemia, Neck.

450. *Berchemia multinervis*, Al. Br., Tert. Flora, p. 277, pl. lii, figs. 9, 10.

Rhamnus, Linn.

451. *Rhamnus alaternoides*, Heer, Tert. Flora, p. 278, pl. lii, figs. 11, 11 *a*.
452. *Rhamnus rectinervis*, Heer, Tert. Flora, p. 279, pl. lii, figs. 12–15.
453. *Rhamnus inæqualis*, Lesqx., Tert. Flora, p. 279, pl. lii, fig. 16.
454. *Rhamnus discolor*, Lesqx., Tert. Flora, p. 280, pl. lii, fig. 17.
455. *Rhamnus Cleburni*, Lesqx., Tert. Flora, p. 280, pl. liii, figs. 1–3.
456. *Rhamnus Goldianus*, Lesqx., Tert. Flora, p. 281, pl. liii, figs. 4–8.
457. *Rhamnus obovatus*, Lesqx., Tert. Flora, p. 281, pl. liv, figs. 1, 2.
458. *Rhamnus intermedius*, Lesqx., Tert. Flora, p. 282, pl. liv, fig. 3.
459. *Rhamnus salicifolius*, Lesqx., Tert. Flora, p. 282, pl. liii, figs. 9, 10.
460. *Rhamnus Rossmässleri*, Ung., Lesqx., Tert. Flora, p. 283, pl. liv, fig. 4.
461. *Rhamnus marginatus*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 420, pl. xxii, figs. 3, 4, 5.
462. *Rhamnus Gaudini ?*, Heer, Newby., Boston Journ. Nat. Hist., 1863, p. 15.
463. *Rhamnus elegans*, Newby., Ext. Floras, p. 49.
464. *Rhamnites concinnus*, Newby., Ext. Floras, p. 50, pl. xvi, fig. 7.

TEREBINTHINEÆ.

JUGLANDEÆ.

Juglans, Linn.

465. *Juglans rhamnoides*, Lesqx., Tert. Flora, p. 284, pl. liv, figs. 6–9.
466. *Juglans Leconteana*, Lesqx., Tert. Flora, p. 285, pl. liv, figs. 10–13.
467. *Juglans rugosa*, Lesqx., Tert. Flora, p. 286, pl. liv, figs. 5, 14; pl. lv, figs. 1–9; pl. lvi, figs. 1, 2.—*Juglans acuminata ?*, (Al. Br.) Lesqx., Annual Report, 1871, p. 288.
467 *a*. *Juglans acuminata*, Al. Br., Heer, Flora Alask., p. 38, pl. ix, fig. 1.
468. *Juglans thermalis*, Lesqx., Tert. Flora, p. 287, pl. lvi, figs. 3, 4.
469. *Juglans Schimperi*, Lesqx., Tert. Flora, p. 287, pl. lvi, figs. 5–10.
470. *Juglans alkalina*, Lesqx., Tert. Flora, p. 288, pl. lxii, figs. 6–9.
471. *Juglans Californica*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 34, pl. 9, fig. 14, pl. 10, figs. 2, 3.
472. *Juglans Oregoniana*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 35, pl. 9, fig. 10.
473. *Juglans laurinea*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 35, pl. 9, fig. 11.
474. *Juglans appressa*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 420, pl. xx, fig. 6.
475. *Juglans Woodiana*, Heer, Foss. Plants of Vancouver, p. 9, pl. 2, figs. 4–7.
476. *Juglans egregia*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 36, pl. 9, fig. 12, pl. 10, fig. 1.
477. *Juglans (Carya) picroides*, Heer, Flora Alask., p. 39, pl. ix, fig. 5.
478. *Juglans nigella*, Heer, Flora Alask., p. 38, pl. ix, figs. 2–4.
479. *Juglans Saffordiana*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 421, pl. xx, fig. 7.
480. *Juglans denticulata*, Heer, Lesqx., Tert. Flora, p. 289, pl. lviii, fig. 1.

Carya, Nutt.

481. *Carya antiquorum*, Newby., Ext. Floras, p. 72, pl. xxiii, figs. 1–4.—Lesqx., Tert. Flora, p. 289, pl. lvii, figs. 1–5; pl. lviii, fig. 2.
482. *Carya verrucosa*, Lesqx., Geol. of Vermont, p. 714, fig. 129.
483. *Carya Vermontana*, Lesqx., Geol. of Vermont, p. 714, fig. 130.
484. *Carya olivæformis*, Nutt., Lesqx., Am. Journ. Sci. and Arts, vol. xxvii, p. 365.

Pterocarya, D. C.

485. *Pterocarya Americana*, Lesqx., Tert. Flora, p. 290, pl. lviii, fig. 3.

ANACARDIACEÆ.

Rhus, Linn.

486. *Rhus Evansii*, Lesqx., Tert. Flora, p. 291, pl. l, fig. 4; pl. lviii, figs. 5–9.
487. *Rhus membranacea*, Lesqx., Tert. Flora, p. 292, pl. lxiv, figs. 6, 7.
488. *Rhus pseudo-meriani*, Lesqx., Tert. Flora, p. 293, pl. lviii, fig. 11.
489. *Rhus rosæfolia*, Lesqx., Tert. Flora, p. 293, pl. xlii, figs. 7–9.—*Weinmannia rosæfolia*, Lesqx., Ann. Report, 1873, p. 415.
490. *Rhus Haydenii*, Lesqx., Tert. Flora, p. 294, pl. lviii, fig. 12.
491. *Rhus metopioides*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 31, pl. 8, figs. 12, 13.
492. *Rhus nervosa*, Newby., Ext. Floras, p. 53, pl. xvi, figs. 5, 6.
493. *Rhus myricæfolia*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 31, pl. 1, figs. 5–8.
494. *Rhus dispersa*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 32, pl. i, fig. 23.
495. *Rhus mixta*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 30, pl. 9, fig. 13.
496. *Rhus Boweniana*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 29, pl. 9, figs. 8, 9.
497. *Rhus typhinoides*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 29, pl. 9, figs. 1–6.

ZANTHOXYLEÆ.

Zanthoxylon, Linn.

498. *Zanthoxylon juglandinum?*, Al. Br., Lesqx., Tert. Flora, p. 294, pl. lviii, fig. 10.
499. *Zanthoxylon diversifolium*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 33, pl. 8, figs. 14, 15.

CALYCIFLORÆ.

HALORAGEÆ.

Trapa, Linn.

500. *Trapa? microphylla*, Lesqx., Tert. Flora, p. 295, pl. lxi, figs. 16–17 *a*.
501. *Trapa borealis*, Heer, Flora Alask., p. 38, pl. viii, figs. 9–14.—Dawson, Am. Boundary Commission Report, p. 330.

MYRTIFLORÆ.

MYRTACEÆ.

Eucalyptus, L'Herit

502. *Eucalyptus Hæringiana?*, Ett., Lesqx., Tert. Flora, p. 296, pl. lix, fig. 10.
503. *Eucalyptus? Americana*, Lesqx., Tert. Flora, p. 296, pl. lix, figs. 11, 12.

ROSIFLORÆ.

POMACEÆ.

Prunus, Linn.

504. *Prunus Caroliniana*, Michx., Lesqx., Geol. of Tenn., p. 427, pl. K, fig. 6.

Amelanchier, Med.

505. *Amelanchier similis*, Newby., Ext. Floras, p. 48, pl. xxv, fig. 6.

Cratægus, Linn.

506. *Cratægus? æquidentata*, Lesqx., Tert. Flora, p. 297, pl. lviii, figs. 4, 4 *a*.

ROSACEÆ.

Spiræa, Linn.

507. *Spiræa Andersoni*, Heer, Flora Alask., p. 39, pl. viii, fig. 3.

Cercocarpus, H. B. K.

508. *Cercocarpus antiquus*, Lesqx., Whitney's Geol. of the Aurif. Dep., p. 37, pl. 10, figs. 6–11.

LEGUMINOSÆ.

Podogonium, Heer.

509. *Podogonium Americanum*, Lesqx., Tert. Flora, p. 298, pl. lix, fig. 5; pl. lxiii, fig. 2; pl. lxv, fig. 6.—*Podogonium* (species), Lesqx., Ann. Report, 1873, p. 417.

Cassia, Linn.

510. *Cassia concinna ?*, Heer, Lesqx., Tert. Flora, p. 299, pl. lix, figs. 8, 8 *a* (enlarged).

Leguminosites, Brgt.

511. *Leguminosites cassioides*, Lesqx., Tert. Flora, p. 300, pl. lix, f. 1–4.
512. *Leguminosites ? arachioides*, Lesqx., Tert. Flora, p. 301, pl. lix, figs. 13, 14.—*Carpolithes arachioides*, Lesqx., Ann. Report, 1872, p. 403.
513. *Leguminosites pisiformis*, Heer, Lesqx., Geol. of Vermont, p. 716, fig. 152.
514. *Leguminosites* sp. (?), Heer, Foss. Plants of Vancouver, p. 10, pl. 2, fig. 8.

Gleditsia, Linn.

515. *Gleditsia triacanthos*, Linn., Lesqx., Am. Journ. Sci. and Arts, vol. xxvii, p. 365.

MIMOSÆ.

Acacia, Neck.

516. *Acacia septentrionalis*, Lesqx., Tert. Flora, p. 299, pl. lix, figs. 9, 9 *a* (enlarged).

Mimosites, Ett.

517. *Mimosites linearifolius*, Lesqx., Tert. Flora, p. 300, pl. lix, fig. 7.

Incertæ sedis.

Phyllites, St.

518. *Phyllites sapindiformis*, Lesqx., Tert. Flora, p. 301, pl. xxix, figs. 6, 7.
519. *Phyllites mahoniæformis*, Heer, Foss. Plants of Vancouver, p. 10, pl. 2, fig. 9.
520. *Phyllites carneosus*, Newby., Ext. Floras, p. 75, pl. xxvi, figs. 1–4.
521. *Phyllites Cupanioides*, Newby., Ext. Floras, p. 74, pl. xx, fig. 5.
522. *Phyllites venosus*, Newby., Ext. Floras, p. 75, pl. xxvi, fig. 4.
523. *Phyllites truncatus*, Lesqx., Trans. Am. Philos. Soc., vol. xiii, p. 423, pl. xvii, fig. 9.

Carpites, Schp.

524. *Carpites lineatus ?*, Newby., Lesqx., Tert. Flora, p. 302, pl. lx, figs. 1–1 *d*.
525. *Carpites oviformis*, Lesqx., Tert. Flora, p. 302, pl. xxx, fig. 6 *a*.
526. *Carpites triangulosus*, Lesqx., Tert. Flora, p. 302, pl. lx, fig. 4, pl. lxii, figs. 19, 20.
527. *Carpites costatus*, Lesqx., Tert. Flora, p. 303, pl. lx, fig. 5.
528. *Carpites coffeæformis*, Lesqx., Tert. Flora, p. 303, pl. lx, figs. 6, 7.
529. *Carpites myricarum*, Lesqx., Tert. Flora, p. 303, pl. lx, figs. 8–11.
530. *Carpites rostellatus*, Lesqx., Tert. Flora, p. 303, pl. lx, figs. 12, 13.
531. *Carpites glumæformis*, Lesqx., Tert. Flora, p. 304, pl. xxxv, fig. 4 *d*; pl. lx, figs. 14–17.
532. *Carpites mitratus*, Lesqx., Tert. Flora, p. 304, pl. lx, figs. 18–19.
533. *Carpites laurineus*, Lesqx., Tert. Flora, p. 304, pl. lx, figs. 20, 21.
534. *Carpites Utahensis*, Lesqx., Tert. Flora, p. 305, pl. lx, fig. 22.
535. *Carpites verrucosus*, Lesqx., Tert. Flora, p. 305, pl. lx, fig. 23.
536. *Carpites minutulus*, Lesqx., Tert. Flora, p. 305, pl. lx, fig. 25.
537. *Carpites Viburni*, Lesqx., Tert. Flora, p. 305, pl. lx, figs. 26, 26 *a*.
538. *Carpites spiralis*, Lesqx., Tert. Flora, p. 306, pl. lx, fig. 27.
539. *Carpites rhomboidalis*, Lesqx., Tert. Flora, p. 306, pl. lx, figs. 28, 29.
540. *Carpites bursæformis*, Lesqx., Geol. of Vermont, p. 715, figs. 146, 147; Tert. Flora, p. 306, pl. lx, fig. 30.
541. *Carpites Pealei*, Lesqx., Tert. Flora, p. 306, pl. lx, fig. 31.
542. *Carpites cocculoides ?*, Heer, Lesqx., Tert. Flora, p. 307, pl. lx, figs. 32–35.
543. *Carpites ligatus*, Lesqx., Tert. Flora, p. 307, pl. lx, figs. 36, 36 *a*.
544. *Carpites valvatus*, Lesqx., Tert. Flora, p. 307, pl. lx, fig. 37.
545. *Carpites Brandonianus*, Lesqx., Geol. of Vermont, p. 713; var. *α*, *elongatus*, figs. 111–113; var. *β*, *obtusus*, figs. 114–117.
546. *Carpites irregularis*, Lesqx., Geol. of Vermont, p. 714, figs. 120, 121, 123, 125, 128.
547. *Carpites Grayanus*, Lesqx., Geol. of Vermont, p. 714, fig. 122.
548. *Carpites venosus ?*, Sternb., Lesqx., Geol. of Vermont, p. 717, figs. 157–160.

Drupa.

549. *Drupa rhadosperma*, Lesqx., Geol. of Vermont, p. 716, fig. 150.

REPORT OF A. S. PACKARD, JR.

INSECTS AFFECTING THE CRANBERRY, WITH REMARKS ON OTHER INJURIOUS INSECTS.

By A. S. Packard, Jr.

The culture of cranberries is rapidly becoming one of some importance in the West, particularly in Wisconsin. There the principal insects, as I have been informed by Mr. F. W. Case, secretary of the Wisconsin State Horticultural Society, are the fire-worm and fruit-worm, but we do not know whether these insects are the same as those found to be injurious to the cranberry in the East or not. I have attempted to bring together all that is known regarding the insects injurious to the cranberry, taken from my "Injurious Insects New and Little Known" (Mass. Agricultural Report for 1870), my "Guide to the Study of Insects," and from unpublished notes. I have been indebted for much valuable information to W. C. Fish, formerly of Sandwich, Mass., and to Mr. F. G. Sanborn. No accounts of cranberry-insects are to be found, so far as I am aware, in the works of any of our entomologists.

INSECTS AFFECTING THE LEAVES.

The Cranberry Span-worm (*Cidaria*, sp.).—The largest worm which is destructive to the leaves is a span-worm or inch-worm (*Cidaria*, species unknown). It was first made known by W. C. Fish, who states that it stripped the plants in Harwich, Mass., in August. On one bog "they destroyed nearly two acres of cranberry-vines, eating off all the green leaves, the bog being as black in spots as though a fire had been over it." I have found that this caterpillar is also destructive in Essex County, Massachusetts. These worms are about the size of and have the same general appearance as a canker-worm. They are dull reddish-brown, simulating the color of the main stem of the plant. The owner of the bog flowed it with water so that it was completely covered, and the worms were killed. This is a rapid and effectual way of exterminating all insects affecting cranberry-plants.

A specimen examined August 26 was of the size of the canker-worm. The head is rather deeply indented above, no wider than the thorax; anal plate long, acute, projecting over the end of the abdomen. The body is dull reddish-brown, simulating the color of the cranberry-twigs; lineated finely and dotted with dark brown. Head speckled with brown, with a conspicuous transverse band across the vertex, with two rows of pale irregular spots across the front; just above the spiracles a broad dusky band, above which are lighter and darker fine thread-lines; beneath paler, with a ventral clear line, edged with dark. The tip of the abdomen ends in two minute acute tubercles tinged with reddish, and ending in a spinule, both situated under the anal plate, and concealed by it when the body is looked at from above. Length, 0.80 inch (20^{mm}).

THE GLISTENING CRANBERRY MOTH (*Tortrix oxycoccana* Packard).—Of the extensive genus *Tortrix*, three species have been found to prey on the cranberry. The present species is said by Mr. F. G. Sanborn to feed upon cranberry-vines. We have briefly described it in our "Guide to the Study of Insects," under the name of *Tortrix oxycoccana*. It was found flying October 4. The body is of a dark slate color, and the palpi, which are large and project well beyond the head, are of the same color, with a few bright reddish scales at the end of the second joint. The tuft of hairs on the tip of the abdomen is much paler than the rest of the body, and of the same color as the legs and the hind wings, being of a glistening gray color. The fore wings are of a uniform reddish-brown color, with a peculiar glistening or greasy hue. The red tint is due to scattered bright-red scales. There are no other spots or markings on the wing, and the fringe is mottled with red and gray scales as on the wings. On the hind wings the fringe is long, silky, glossy, grayish white. Beneath, the fore wings are pale gray, the hind wings being paler than the fore wings. Length of the body, .25; expanse of the wings .64 of an inch. It may be readily known by the peculiar shining, greasy look, and by the rich, red scales scattered over the plain, unadorned fore wings. The habits of the caterpillar are not known.

THE YELLOW CRANBERRY WORM (*Tortrix vacciniivorana* Packard).—August 4, I received from New Jersey, through Mr. S. H. Scudder, specimens of this insect in all its stages, under the name of the "cranberry-worm." It seems to be a common insect in the cranberry-fields of New Jersey, but has not yet been found in the New England States. It was new to science, and was called the *Tortrix vacciniivorana*. The larva draws the leaves together with silken threads, transforming into a pupa within the mass. A single larva seems to select one twig or branch, and eats the parenchyma from the upper surface of the leaves until every leaf or twig is injured, and the plant nearly as much destroyed as if the leaves were eaten up entirely. In this way, each larva seems to eat the best part of about twelve leaves, which usually remain on the stalk, affording a shelter to the pupa, which is naked, partly sticking out of the leaves.

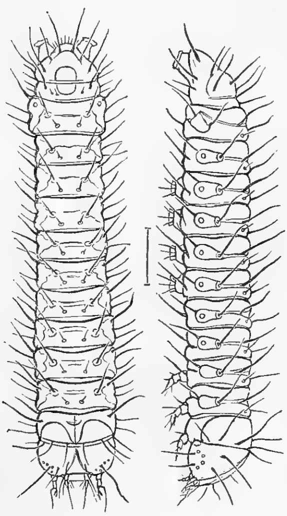
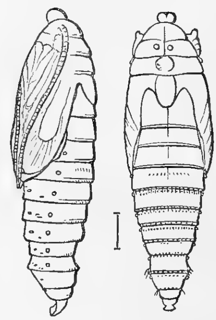

FIG. 1.—Yellow Cranberry Worm and Pupa.

The larva is pale honey-yellow, with a slight greenish tinge. The head and prothoracic shield are pale honey-yellow, and the head is nearly as wide as the prothorax. The body tapers gradually to the tail, and is furnished with fine, sparse, pale hairs arising from prominent tubercles, the hairs being one-half as long as the body is wide. The four dorsal tubercles are arranged in a trapezoid, with a deep crease between the anterior and posterior pair. The thoracic feet are tipped with black. On each side of the base of the head is a lateral S-shaped blackish-

brown linear band, the upper part of the S terminating on the top of the occiput, the line being most distinct on the side of the head. The ocelli are black. It is .27 of an inch in length.

Mr. Trouvelot, who made the admirable drawings here engraved, wrote me as follows regarding its habits: "Like the larvæ of the *Hesperidæ*, as in *Endamus* and *Tityrus*, this cranberry-worm sends off the excrement to some distance when it defecates. When it had built an imperfect cocoon, it was very careful to remove the pellets of excrement in it, by taking them with the mandibles and carrying them out."

The pupa is brown, rather slenderer than usual, with the vertex of the head prolonged into a large tubercle, surmounted by a round knob, which is rough, while the tubercle below is smooth; there is an angular projection on each side of the base of the tubercle, forming a shoulder to it. The wing-covers reach to the end of the third abdominal ring, while the antennæ reach to the end of the second pair of feet, which are parallel to the end of the second abdominal ring. There are two rows of teeth on the upper side of the abdominal rings; they are obsolete beneath, the posterior row being indicated by two remote minute tubercles. Length .25 of an inch.

The moth is rather undersized, with yellow wings, without any decided markings, but mottled with deep ochreous. It expands one-half of an inch.

THE RED-BANDED CRANBERRY TORTRIX (*Tortrix incertana*).—This *Tortrix*, described by Dr. Clemens under the name of *Tortrix incertana*, was originally sent to Mr. Sanborn by Miss Guild, of Walpole, Mass., where its larva is called the "cranberry-worm." According to the late Mr. C. T. Robinson, it is found in Texas, and northward to Ohio and Pennsylvania, as well as Massachusetts.

The body and fore wings are deep reddish-brown. The palpi are prominent, projecting farther than usual in front of the head. The head and thorax are ochreous-brown, with a large tuft of red hairs on the hinder margin of the thorax. The fore wings are reddish-brown, and at the base clear light reddish-brown, bounded behind by a curved broad dark-brown band, which terminates just below the median vein; between this and the broad brown-red band, and situated on the inner edge of the ring, is a dull-silvery equilaterally-triangular spot. From the middle of the costa runs to the outer angle of the wing a broad dull-red band, one-half as wide as the ring, and suddenly narrowing on the costa. Beyond is a narrow hemispherical dark-red costal spot. Beyond the broad band the outer edge of the ring is clear silvery, except an oval brown spot. The fringe is reddish, silvery on the inner margin. The hind wings are pale, smoky, concolorous with the under side of the fore wings, while the under side of the hind wings is whitish. It expands .70 to .80 of an inch.

In the pupa the segments of the abdomen are divided by deep sutures, the edge being angulated, and with two dorsal rows of unusually small spines. The tip is prolonged into a long point, nearly twice as long as wide, and giving rise to three pairs of curved minute filaments. Length, .34 of an inch.

THE RED-STRIPED CRANBERRY WORM.—This worm I observed, September 20, to be common on the heads of cranberry-plants in Hamilton, Mass., drawing the leaves together, eating off one side of a leaf, either wholly or in part, and eating the parenchyma, leaving the reverse side untouched. Twelve or fourteen terminal leaves are usually thus eaten; sometimes the terminal leaves are not touched, the caterpillar working up from below. The leaves are either drawn together by

a few silk threads, or there is a regular tube of silk situated between two leaves, the latter severed from their connection with the branch, but held in place by silk threads, the leaves consequently turning brown; the heads of the branches are thus withered for about an inch, so that patches of the cranberry-bed are brown and withered.

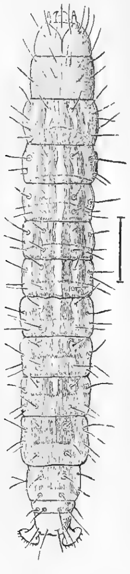

FIG. 2—The Red-striped Cranberry Worm.

Body long and slender, tapering a little toward the head, but more toward the tail. Head about three-fourths as wide as the middle of the body. Pale testaceous, with a few long hairs. Mandibles reddish, dusky at tips. Ocelli blackish. Prothorax unusually long, nearly as long as the head, elongate lunate, with no markings on it, slightly wider than the head, but decidedly narrower than the succeeding segment. Body pale livid green, with six longitudinal pale-reddish lines, broken and irregular toward the head, but more distinct and wider toward the tail, so that the body looks darker and rather reddish posteriorly. On the front edge of the second and third rings a transverse row of six black minute warts giving rise to a hair, and a seventh one low down in the middle of the side. On the abdominal segments four dorsal black warts, the two anterior nearer together than the posterior, though not forming a decided trapezoid; on side of ring another black wart in line with the two anterior dorsal ones, and giving rise to a rather stout hair. Around the edge of the supra-anal plate a row of four black warts, and two median dorsal smaller warts. Beneath, livid-greenish, the three segments between the last pairs of feet with each a transverse straight row of minute black warts.

THE CRANBERRY-VINE WORM (*Anchylopera vacciniana* Packard).—Our account of this insect is taken as follows from our "Guide to the Study of Insects," while the figures are engraved from original drawing made by Mr. Emerton.

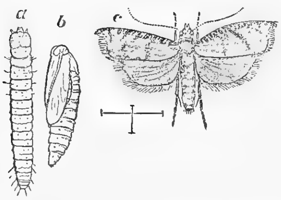

FIG. 3.—Cranberry-Vine Worm, enlarged.

Mr. Fish has discovered an undescribed species which feeds on the cranberry, and which we may call the Cranberry *Anchylopera* (*A. vacciniana*). The moth is dark ash, the fore wings being whitish, dusted with brown and reddish scales, with white narrow bands on the costa, alternating with broader yellowish-brown bands, five of which are several times larger than the others; from four of them irregular indistinct lines cross the wing. The first line is situated just beyond the inner third of the wing, and is often obsolete. The second line is the largest, and is slightly bent once in the middle of the wing. There is a large brown spot parallel to the costa, being situated on the angle. The third line is oblique and stops before reaching the inner angle, and is forked on the costa, while the fourth line is a short apical diffuse irregular line. The apex of the wing is dark brown, and is a little more acute than usual in the genus. The length of a fore wing is .28 of an inch. It lays its eggs on the leaves during the month of August, and a new brood of larvæ appears in September, though they hatch mostly in the following spring or early in June, and become fully grown in July.

The larva seen from above is much like that of *Lozotænia rosaceana*, but the head is a little larger in proportion to the rest of the body, being as wide as the body in its thickest part. The body is more hairy, while the prothorax is not dark. The chrysalis is rather slender, the

body being contracted at the base of the abdomen, on the rings of which there are dorsal rows of fine spines.

Mr. Fish writes me that "these larvæ, called the cranberry-vine worms, hatch about the 1st of June from eggs that have remained upon the leaves of the plant all winter. They commence to feed upon the tender growing shoots of the plant, drawing the leaves together with their net for shelter, concealing themselves and feeding within. Before reaching their full size they, if very numerous, almost wholly destroy the leaves and tender shoots, giving the whole bog a dark dry appearance, as though a fire had been over it. This is why they are in some places known as "fire-worms." Having reached their full size they spin among the leaves or among the dead leaves upon the ground. After remaining in the pupa state about ten or thirteen days the moths come out and deposit their eggs upon the leaves. This year the moths were out the last of June and first of July. In five or six days the eggs hatched, and this second brood, which is usually the most destructive, mostly changed to pupæ on the 20th of July. On the 26th of July the first moth came out, and most were out before the 4th of August. I saw the moth at Sandwich as late as the 20th of August. Most of the eggs laid in August do not hatch until the following spring. I did succeed in finding two or three larvæ in September, but they were rare at that time. The only sure means known of destroying them is to let water upon the bog for twenty-four hours."

Besides the moths and their caterpillars mentioned above, there are two other insects which derive their nourishment from the leaves. Mr. Fish has noticed plant-lice (*Aphis*) on the cranberry-vines.

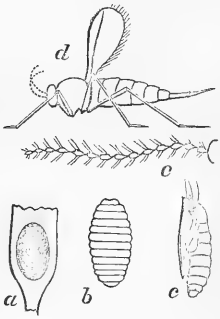

FIG. 4.—Cranberry Gall-Fly.

A species of *Cecidomyia*, or closely allied genus belonging to the family of dipterous gall-flies, has been discovered by Mr. Fish attacking the leaves. The following figures, reduced from sketches made by Mr. F. G. Sanborn, will serve to give some idea of the transformations of this insect. The larva (*b*) is pinkish, and of the form indicated in the cut. It spins a cocoon (*a*) on the leaves apparently, and changes within the cocoon to a chrysalis (*c*); *d* represents the female, much enlarged, her body ending in a long retractile point; *e* represents the female antennæ, much enlarged. It is not likely that this insect does much harm.

ATTACKING THE FLOWER-BUD.

THE CRANBERRY WEEVIL (*Anthonomus suturalis* LeConte).—Mr. W. C. Fish has found this insect preying on cranberry-buds, and communicated to me an account of its habits. It was identified by Dr. J. L. LeConte as *Anthonomus suturalis* Lec., and I extract the following description of it from my "Guide to the Study of Insects," p. 487: "It is a minute reddish-brown beetle, with the beak one-half as long as the body, just beyond the middle of which the antennæ are inserted. The head is darker than the rest of the body, being brown-black. The thorax is a little darker than the elytra, and covered very sparsely with short whitish hairs; the scutellum is whitish, and the elytra are shining reddish-brown, with the striæ deeply punctured, the interstices being smooth. It is .13 of an inch long, including the beak. Mr. W. C. Fish detected this little weevil laying its eggs in the buds of

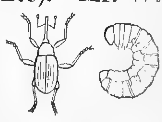
FIG. 5.—Cranberry-Bud Weevil.

the cranberry. It selects a bud not quite ready to open, and, clinging to it, works its snout deep into the center of the bud. An egg is then deposited in the hole made, when the beetle climbs to the stem and cuts it off near where it joins the bud, which drops to the ground and there decays, the egg hatching, and the grub going through its transformations within. The larva is long and rather slender, cylindrical, the body being of uniform thickness and curved; the head is pale honey-yellow; the jaws tipped with black; the segments of the body are very convex, especially the prothoracic one; it is white, with a few fine pale hairs, and is .08 of an inch in length."

Mr. Fish, in an article on this insect, published in the Yarmouth Register, states, in addition to what we have said above, that the "egg, which may be found within the bud, is pale honey-yellow, and is very minute, measuring but .02 of an inch. The egg hatching, a dull whitish grub will be found feeding within the bud. Having attained its growth it changes to a pupa, and the perfect weevil eats its way out of the bud, leaving a round hole in the side. These beetles may be found upon the vines some time after the blossoms have disappeared. I have known them to eat into a cranberry, making a round hole large enough to admit the insect, but it is seldom that it does this. It also eats a little upon the under leaves, but I have never known it to deposit its eggs within the fruit, and I have never found the grub elsewhere than in the bud. I have taken this beetle upon the fruit of the blackberry, in company with other species of *Anthonomus*. This insect is not numerous anywhere, but is more common at Eastham than at any other locality that I have visited. As I have never seen one upon a bog that had been flowed during winter, I think that it will never become troublesome on such bogs at least. The larvæ are killed by a minute chalcis-fly, as I discovered the past season."

ATTACKING THE FRUIT.

The mature fruit is attacked late in the summer and in the autumn by the "fruit-worm." This is a small caterpillar belonging to the same family as the leaf-rollers. The first segment behind the head is rather large and square, and the body is less hairy than in the leaf-eating species. This worm is common in Massachusetts. It appears the first of August, and works through the month. The first signs of its presence are seen in the premature reddening of the berries. Most of the worms attain their full size before the first of September; some may be found in the winter. Mr. Fish states that when the caterpillar is fully grown it enters the earth and spins a cocoon within a few inches of the surface. The cocoon is covered with grains of sand, and resembles a lump of earth. It remains in the ground all winter. An ichneumon preys upon the caterpillar. Unfortunately we do not know the parent of the caterpillar.


FIG. 6.—Cranberry Fruit Worm.

These are the only insects thus far known to prey upon the cranberry, and occasionally one or several of them prove very destructive, locally.

In applying remedies, the most general and applicable is to flood the cranberry pastures or bogs. The vines should be kept under water for at least two or three days, as many insects will survive several days' immersion. Fires at night will attract the moths, and numbers may be destroyed in this way. Pans of coal-oil, and the use of coal-oil on the puddles and standing water in which the vines grow, may be tried, should it be found by previous experiments that the mineral oil does not injure the vines.

INJURING THE PINE.

THE PITCH-PINE GALL-FLY (*Diplosis pini-rigidæ*, n. sp.).—Several years ago I observed in an isolated young pitch-pine (*Pinus rigida*) at Brunswick, Me., that the leaves were less than half as long as usual, and much swollen at their base, as seen in the adjoining cut.

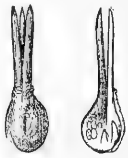

FIG. 7.

These deformed needles were quite numerous on the tree, and have not been previously noticed, so far as I am aware.

The larva is deep orange, with the breast-bone retractile. The lateral region of the body is well marked, convex, and the segments are short, quite convex. The larva is situated at the base between the inner two of the three needles, which grow from one-third to one-half of their normal length, and by the irritation set up by the worm the united base of the leaves swells into a bulbous expansion about the size of a pea, or four times the original thickness of the needle, while the third or outer leaf is sometimes not altered in size, only shortened, and aborted. The bud-scales of the primary leaves are burst and hang down in shreds about the bulbous swellings of the secondary leaves or needles.

The larva (found September 22) does not apparently bore into the leaves, as it has no means of making its exit unless it works its way out of its prison through an oval hole between two of the leaves. It has to in some way, for when fully fed it makes its exit, ascends to the terminal buds, and pupates on one of them, exposed to the air. Sometimes there are two larvæ, one on each side of a leaf.

The cocoons are pale, oval, and covered with the pitch which exudes from the buds of the tree, and were found May 20.

When the fly issues from the cocoon it creeps half way out of its cocoon, leaving its pupa-skin partially remaining, with the old pupal integument of the antennæ, wings, and legs separate.

June 10, I opened the cocoon and found the pupæ of a chalcid-fly, and afterward found specimens of the adult, which bore small holes through the sides of the cocoon.

Adult female described from life: Antennæ 14-jointed, about half as long as the body, brown, with sparse, irregular verticils of gray hairs, the ten terminal joints twice as long as broad, and pedicellate. Clypeus and epicranium testaceous brown, the clypeus (hypostoma) having a few long gray hairs curving over and downwards. Palpi concolorous with the ends of the antennæ.

Thorax shining black, with four lines of white hairs, as in *C. pini* De Geer; the sides, including the prothorax, reddish; scutellum reddish-brown, while the trochanters are much darker, the first pair being nearly black, the two posterior pairs reddish-brown. Legs brown, paler beneath, with gray hairs, the tarsal joints darker at the articulations, covered with fine silvery hairs.

Wings rather short and broad, with scarcely any pubescence; fringe long, veins dark brown; the subcostal (first longitudinal) terminates at the middle of the wing (in *C. salicis* it terminates much beyond this point); the median vein terminates at or perhaps a little below the apex; it curves around rapidly, following the curve of the margin; cross vein very minute, very oblique, almost obsolete, situated a little before the middle of the first longitudinal vein; third longitudinal vein straight, but turning down to the inner margin at nearly a right angle. The venule, in continuation of the main vein, is bent upwards at its

origin, and thence goes straight to the outer edge, inclosing a triangular space. The halteres pale flesh-colored.

Abdomen blood-red, with slight sparse hairs. The segments on the terminal half of the abdomen are edged with black, and the tip of the abdomen is blackish, while the genital armature is flesh-colored. Length, .10 inch.

This species differs decidedly from *Diplosis pini* Loew ♀, in that the basal joints of the antennæ are not yellow, but pale brown. The clypeus (hypostoma) is reddish-brown, not reddish-yellow. The abdomen is blood-red, and the hairs are too few to give a silvery reflection; the legs do not seem whiter beneath than above; the wings are not densely pubescent, but are sparingly so. The cross-vein is difficult to find, and then is only seen in certain positions. It is smaller, being only a tenth of an inch long.

In its habits it seems to differ from Osten Sacken's *D. pini inopis* in that the apparently similar pale, oval, resinous, pitchy cocoons are placed on the buds of the pine-needles, which were somewhat deformed, and could thus be easily distinguished from others not affected, as well as by the resinous pitchy exudation covering them. (Observed May 20.) The food-plant is also different, the *D. pini inopis* living on *Pinus inops*, Jersey or scrub pine, which does not extend so far north as New England.

THE PINE MONOHAMMUS (*M. confusor* Kirby., *M. titillator* Harris).—Nothing was known of the habits of this borer by Harris, in the third edition of whose treatise the beetle is well figured. In 1860, Dr. Fitch gave an excellent account of the habits and brief description of the larva and pupa and adult in his Fourth Report on the Noxious Insects of New York. The following description of the larva and pupa is based on specimens obtained at Brunswick, Me., and compared with some received from Mr. F. C. Bowditch, who published in the American Naturalist, August, 1873 (vii, p. 498), an account of the habits and transformations. He sent me a block of pine wood split off, containing the terminal portion of the cell, stuffed with large chips, arranged quite regularly. In the museum of the Peabody Academy of Science, at Salem, is a piece of planed plank, which had been sawn so as to uncover part of the hole, with the beetle within, as seen in Fig. 8. Fitch states that this and

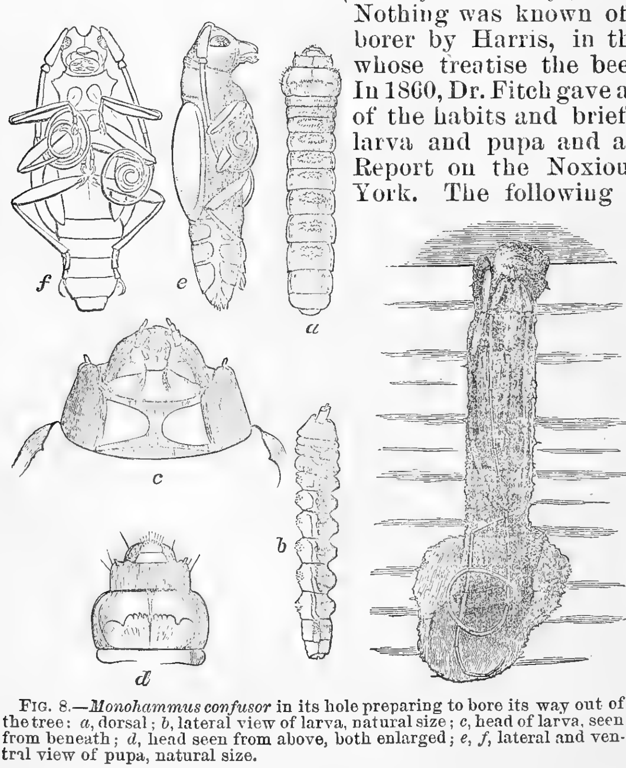

FIG. 8.—*Monohammus confusor* in its hole preparing to bore its way out of the tree: *a*, dorsal; *b*, lateral view of larva, natural size; *c*, head of larva, seen from beneath; *d*, head seen from above, both enlarged; *e*, *f*, lateral and ventral view of pupa, natural size.

Monohammus scutellatus and *marmoratus* are the most common and pernicious borers which occur in the pine timber of New York. "On a still summer's night the peculiar grating or crunching noise which the larvæ make in gnawing the wood may be distinctly heard at a distance of eight or ten rods. That the insect does not open a passage out of the wood, whereby to make its exit, until it attains its perfect state, I infer from the fact that several of these beetles gnawed their way out of one of the pillars of the portico of a newly-built house in my neighborhood some years since, the noise being heard several days before they emerged, and while they were still at some distance in the interior of the wood."

Mr. Bowditch found, June 9, at Brookline, Mass., this species in *Pinus mitis*, the yellow pine, in which were several holes about the size of a pencil. "On removing the bark I found an adult insect already free and the heads of several others appearing through the wood. On further investigation during the next few weeks I obtained from the tree no less than eighty of these beetles in all stages of development, which, considering the size of the tree, was a large number. I observed that the largest beetles were near the foot of the tree. * * * After remaining in the pupa state during a space of time which varies according to circumstances, it is transformed to a beetle, and after a short time gnaws its way out, appearing from the first of June to the middle of July."

I have found numbers, at least twenty, of these larvæ under the bark of the white pine (*Pinus strobus*) at Brunswick, Me., in the early part of June, but no pupæ or beetles, though most of the larvæ were fully grown. Some were one-half an inch long, and had, without much doubt, hatched from eggs laid in the preceding June or July, so that the larvæ must live nearly two years before transforming. My attention was called to their presence in the tree by the creaking made by the larvæ, the noise being heard a rod from the tree. Some of the larvæ were molting. In this process the entire head of the tegument about to be cast is pushed off anteriorly, while the thin skin of the rest of the body peels off from the prothorax backwards.

Mr. A. C. Goodell, of Salem, Mass., presented the museum of the Peabody Academy with an adult of this species which came from a pine bureau about the year 1875. The bureau had been in the house for about fifteen years previous, being newly made when purchased. The family had heard the creaking noise for some time before the insect appeared; and, after inquiring into the circumstances, I have no doubt but that the insect had lived in the bureau for fully fifteen years.

This longevity is probably due to the fact that the insect had not coupled, it being well known that continence in insects leads to the prolongation of life far beyond their natural term of existence. Further observations and experiments on this point are greatly needed.

Apropos of this interesting subject I quote the following observations of Dr. Fitch:*

"The wood of the apple-tree was formerly highly valued for cabinet-work in this country. In 1786, a son of General Israel Putnam, residing in Williamstown, Mass., had a table made from one of his apple-trees. Many years afterward the gnawing of an insect was heard in one of the leaves of this table, which noise continued for a year or two when a large long-horned beetle made its exit therefrom. Subsequently the same noise was heard again, and another insect, and afterward a third, all of the same kind, issued from this table-leaf; the first one coming out

* Third Report on the Insects of New York. By Asa Fitch. Trans. N. Y. Agric. Soc., 1856, p. 326.

twenty and the last twenty-eight years after the trunk was cut down. These facts are stated more fully in the History of the County of Berkshire, published at Pittsfield in 1829, p. 39. This, I believe, is the longest period of an insect remaining alive in timber of which we have any record, and it is desirable to ascertain, if possible, what insect this was. John J. Putnam, esq., of White Creek, N. Y., was a young man residing at his father's when these remarkable incidents occurred. On showing to him specimens of all the larger long-horned beetles of this vicinity, he points to *Cerasphorus balteatus* as being the same insect, according to the best of his recollection, but is not certain but it might have been the *Callidium agreste*."

"This testimony, in connection with what President Fitch, of Williams College, says of the insect in the notice above referred to—'Its color dark glistening brown, with tints of yellow'—releases us from all doubts upon this subject, as the *agreste* is of a uniform brown, whilst the *balteatus* commonly presents traces, more or less distinct, of an oblique yellowish spot or band near the middle of the wing-covers."

Larva: Body soft, white, long, nearly cylindrical, being but slightly flattened, entirely footless, all the abdominal segments of the same width, except the minute small one. From the first abdominal (or fourth from the head), the body increases in width, being widest on the prothoracic segment (or the one next to the head). This segment is transversely oblong, being as wide in front as behind; it is a little more than twice as wide as long. The head is large and square, not narrowing in front, but as wide anteriorly as posteriorly. When the head is forcibly pulled out it is found to be as long as broad; anterior one-fourth of head deep mahogany red, becoming blackish on the edge. Clypeus very short and broad, about four times as broad as long. Labrum rather wide, not much contracted at base, rounded in front, with very stout bristles on the margin. Mandibles gouge-like, the end oblique, hollowed out, with the outer edge produced into a point. Antennæ very minute, three-jointed, the second and third joints about as long as the basal. The maxillæ form a basal joint throwing off a three-jointed palpus, and an inner lobe armed with stiff bristles reaching to the end of the second joint of the palpus. The two-jointed labial palpi reach to as far as the middle of the brush-like lobe of the maxillæ; the second joint is about as long, but half as wide as the basal. The middle of each segment, especially the third to the seventh above and below, with a transverse callous spot. The upper side of the first abdominal segment has a very narrow oblong square area impressed upon it. The callous spot is best marked on the fifth segment, consisting of an area about one-third as long as broad, with a square shallow sinus posteriorly, and with the sides projected inwards; it consists of two series of callous spots, the outer forming the limits of the area as above described, and the inner series forming a simple transverse narrow lanceolate oval spot. The callous spot on the under side has a sinus in front, but slightly rounded behind. The one on the seventh segment (below) is but little more than one-half as wide, with a broad sinus on the hind edge, and with the sides directed obliquely inwards. Terminal segment very small, half as wide, and one-fourth as long as penultimate segment. Nine spiracles, first on front edge of second thoracic (mesothoracic) segment.

Length when fully grown, 1½ inches. This larva may be known from that of *Rhagium lineatum*, by its much longer, more cylindrical body, and differs at once, by the long square head, that of *Rhagium* rounding in front, by the wider clypeus, and proportionately wider and shorter labrum. The palpi and antennæ do not differ much. The callous spots

on the abdominal segments are smaller and otherwise different from those in *Rhagium.*

Pupa: The pupa is far advanced, being nearly ready to change to a beetle, the body becoming dusky and horn-colored, while the characteristic dark spots have already appeared on the wing-covers. The antennæ are coiled up three and a half times at the end between the fore and middle pair of legs, and the genus may be recognized by their great length, and the deep excavation in the head between them, as well as by the lateral short spine on the prothorax.

The wing-covers in my single specimen reach to the third abdominal segment and are pressed obliquely to the side of the body. The salient portions of the upper side of the abdominal rings with fine spines. End of the body sinuate.

In the absence of another pupa of this genus for comparison, additional characteristics cannot now be given. Length, three-quarters of an inch.

THE HORN-TAIL BORER (*Tremex Columba* Linn.).—This insect in the larva state was found by some students in the Massachusetts Agricultural College, at Amherst, Mass., early in October, in a tree on the college-grounds. With the larvæ were associated several imagoes which had not left their holes, and seemed likely to be destined to pass the winter in the tree. As the transformations of this insect have not been known heretofore, we add the following description of the larva.

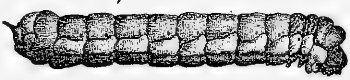

FIG. 9—Larva of Tremex Columba, natural size.

Larva: A long white cylindrical worm, with the segment behind the head of the same width as the twelfth segment from the head; the thirteenth much narrower, regularly rounded behind, with a deep crease above, leading backwards and a little downward to a small sharp terminal dark-reddish horn. The horn is acute, with three teeth above near the base, and two smaller ones on the under side. Each of the three last rings bulges out on the under side. The head is white, and about half as wide as the segment behind, into which it partially sinks. It is rounded, smooth, with the antennæ represented by small rounded tubercles, ending in a minute horny spine; should the spine be regarded as indicating a joint, then the appendage is three-jointed. The clypeus is broader than the labrum by a distance equal to its own length. The labrum is a little more than twice as broad as long, with the front edge slightly sinuous. The large powerful mandibles are four-toothed on one side and three-toothed on the other. The maxillæ are three-lobed, the lobes unequal, ending in spines, the middle lobe with two spines, the outer lobe much smaller than the others. The labrum or under lip is rather large, rounded, with a spine projecting on each side. The prothorax or segment next behind the head is twice as long as the one behind it, divided into two portions by a suture behind it. There are three pairs of small soft unjointed feet, of which the first pair are considerably the largest; they do not project straight out but are pressed to the body and directed backward.. There are ten pairs of spiracles, one pair on the hinder edge of prothorax, twice as large as the others; the second pair between the second and third rings, and the eight others on the eight basal abdominal segments.

Length, 2.25 inches; greatest thickness, .28 inch.

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